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RECENT ADVANCES IN OUR KNOWLEDGE OF THE VITAMINS

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If one examines a present-day chemical catalogue the following compounds may be listed under the heading of vitamins: vitamin A alcohol, carotene, vitamin D_2, vitamin D_3, α-tocopherol, 2-methyl-1,4-naphthoquinone, l-ascorbic acid, thiamine hydrochloride, riboflavin, nicotinic acid, pyridoxine, calcium pantothenate, choline chloride, crystalline biotin, p-aminobenzoic acid, inositol, etc. Those who have not followed closely the vitamin literature may be surprised at this array of compounds and wonder how they are related to practical nutrition.

In the first place it is evident that tremendous advances have been made in our knowledge of the chemistry of the vitamins since it is not so long ago that a crystalline vitamin was a laboratory curiosity and an amount of a pure vitamin sufficient to feed a group of rats for several weeks cost hundreds of dollars. To-day we think nothing of purchasing many of the vitamins in good-sized bottles or even in kilogram lots.

Vitamin A alcohol, carotene, vitamin D_2 and vitamin D_3 are the pure forms of the two oldest and best-known fat soluble vitamins. They are still made from natural products, since neither of these vitamins is being produced synthetically, although considerable progress has been made recently in developing methods for producing synthetic vitamin A. Much of the vitamin A in natural diets is supplied by milk and milk products and green vegetables and for many years any supplementary vitamin A was added as fish-liver oils. Highly active concentrates of both vitamin A and carotene are now used for fortification of foods and in vitamin capsules. Vitamin D was similarly supplied by fish-liver oils but recently refined sterols are activated for the production of vitamin D concentrates. The pure preparations are valuable as standards for the determination of these vitamins in foods. For many years pure beta carotene has been used as the standard but it is also important to have pure vitamin A available since it is now rather definitely established that carotene is not assimilated as readily from the intestinal tract as the vitamin A alcohol. Vitamin D_2 is used as the standard for vitamin D although it is well known that in the chick vitamin D_3 is much more active than vitamin D_2. In the human the difference in activity is negligible. This brief discussion of these two well-known vitamins brings out a fact which is true for most of the vitamins, namely, that several related compounds may have similar biological action but the degree of their activity varies. In the case of vitamin D at least 10 different compounds are known to

have antirachitic properties, but vitamins D_2 and D_3 are the most important ones. It is also interesting to compare the actual weight of the compound needed to produce the desired effect in the case of different vitamins. The human requirements for vitamins A and D are generally expressed in International Units but on a weight basis 1.5 mg of vitamin A or 3 mg of carotene will meet the daily vitamin A requirement, while only .01 mg of vitamin D is an adequate daily intake of this vitamin.

Alpha-tocopherol is a light yellow viscous oil and is now available in synthetic form as the most potent source of vitamin E. Again other tocopherols show vitamin E activity, but the alpha form is the most active. Although vitamin E was first recognized as a vitamin essential for normal reproduction in rats, it now has a much wider significance. As early as 1928 it was observed that suckling rats born of mothers which had received just enough vitamin E to permit successful gestation developed a characteristic paralysis. Muscle dystrophy has been produced in many different animals by depriving them of their vitamin E intake. The muscle dystrophy is accompanied by an increased excretion of creatine and an increased rate of oxygen uptake in the muscle tissue. The cure of nutritional muscular dystrophy in animals is abundantly proved, but vitamin E therapy in neuromuscular diseases in humans has not been too successful. The availability of alpha-tocopherol will allow more extensive study of human cases. At present there is no indication that natural diets are low in vitamin E and therefore it has no value in the fortification of foods.

The compound 2-methyl-1,4-naphthoquinone probably does not exist in nature as such, but still it shows greater vitamin K activity than any of the natural forms of this vitamin. The original work on vitamin K was quite independant of any human disorder. In 1929 Dam observed that chicks raised on certain artificial diets became anemic, developed intramuscular hemorrhages and showed a marked increase in the clotting time of the blood. He concluded that the disease was due to a lack of hitherto unknown dietary factor and vitamin K was used to designate the factor. During the period 1935–1940 assay methods involving the chick were developed and vitamin K_1 and K_2 were isolated and their structures established. Almquist first discovered the vitamin K activity of the simple quinone 3-hydroxy-2-methyl-1,4-naphthoquinone and later Ansbacher and Fernholz showed 2-methyl-1,4-naphthoquinone to be 3 to 4 times as active in the chick assay as vitamin K_1. Both K_1 and K_2 contain the naphthoquinone nucleus but a longer side chain makes them soluble in fat. The compound, 2-methyl-1,4-naphthoquinone, now called Mendione, is used as a standard in vitamin K assays and in clinical work. Certain derivatives of Mendione are now available which are more soluble in water than the original compound. It is very difficult to produce a vitamin K deficiency in mammals or humans by dietary means but this vitamin is of distinct value in maintaining a normal prothrombin level in new born infants and in adults with decreased intestinal absorption such as obstructive jaundice. Under normal conditions there is considerable synthesis of vitamin K by the bacteria of the intestinal tract and therefore the supply of this vitamin in the normal diet is not as important as in the case of other vitamins.

l-ascorbic acid or vitamin C has the distinction of being the first vitamin to be produced in synthetic form. The compound was actually isolated in 1927, but five years passed before the biological activity of the compound was recognized. In 1932 King and Waugh dem-

onstrated the identity of vitamin C and hexuronic acid, now known as ascorbic acid. The importance of a specific configuration in a biologically active compound is clearly illustrated in the case of vitamin C, since l-ascorbic acid is highly active but d-ascorbic acid is completely inactive. To-day ascorbic acid is so readily determined by chemical methods that it is difficult to realize that we used to have to rely upon the long and tedious guinea pig assay. This vitamin is widely used in clinical work but its use in fortification programs is rather limited, for several reasons. Vitamin C is easily and cheaply supplied by fruits and vegetables in the diet and it is easily destroyed when mixed with many natural products. The synthetic material has had an interesting application in farm practice during the past few years. Although cattle are able to synthesize sufficient vitamin C to meet their own requirements, the amount of synthesis is greatly reduced in vitamin A deficiency. In such cases the injection of vitamin C has had a very beneficial effect on the sterility which develops.

Thiamine hydrochloride is a white crystalline substance readily soluble in water and possessing a yeast-like odor. Due to the well-known efforts of R. R. Williams and cooperating manufacturing chemists this important compound may now be purchased at a wholesale price of 40 cents per gram. The price is of even greater significance when we realize that one gram of thiamine is sufficient to supply the requirement of one adult for almost two years. We used to teach that the vitamin-carrying foods was the costly part of our diet, but this most encouraging experience indicates that the only limitation in making vitamins readily available to large groups of the human population is the original identification and isolation of the vitamin.

In foods and in animal tissues thiamine occurs both in the free form and as cocarboxylase. In this latter form it functions in the living cell as a coenzyme in carbohydrate metabolism. Thiamine can be oxidized to thiochrome, which shows fluorescence and the degree of fluorescence produced may be used as a measure of the amount of thiamine in food. This simplified procedure has been of the greatest value in establishing the thiamine content of common foods. In fact, our knowledge of the distribution of thiamine in the wheat kernel was very limited until this improved method was made available. Since almost 90 per cent. of the original thiamine in a wheat kernel is lost during the milling of the patent flour, white flour and bread is now being enriched with thiamine to a level of 1.6 to 2.5 mg per pound of flour. In order to meet this demand and other requirements, tons of synthetic thiamine are now produced annually in the United States.

It is most encouraging to find riboflavin listed with the other vitamins, since its structure is probably the most complex of the water soluble vitamins and it still can not be manufactured fast enough to meet the demand for it. Its addition to enriched flour has been postponed several times by the Federal Security Agency because of an insufficient supply. In spite of the difficulty in producing sufficient quantities the price has steadily decreased. Riboflavin was first recognized as a component of an important respiratory enzyme and has since been found to be related to several enzyme systems. Its importance in human nutrition was not recognized until 1938, but since that time significant advances have been made regarding the value of this vitamin in maintaining optimum health. This vitamin is rather widely distributed in foods, but the most reliable sources are milk, meat and vegetables. In certain areas of this country the consumption of these food

products is low enough to allow the development of a riboflavin deficiency. The use of pure riboflavin in these areas is therefore justified at least as an emergency measure.

Nicotinic acid has been available as a chemical compound for over fifty years but its nutritional significance did not become evident until 1937. Nutritional workers experienced considerable difficulty in studying the anti-pellagra factor because a syndrome similar to human pellagra could not be produced in any of the laboratory animals except the dog. In 1937 it was shown that nicotinic acid would cure black-tongue in dogs and very shortly thereafter the value of this compound in the treatment of human pellagra was definitely established. It is now possible to explain the earlier difficulties because the rat does not need nicotinic acid preformed in its diet, while the dog and the human do require this factor. Nicotinic acid is a very simple compound and functions in the animal body as a constituent of certain coenzymes. At first it was necessary to depend upon assays with dogs for the determination of the nicotinic acid content of natural foods, but within the past year or two both microbiological and chemical methods have been developed which are very reliable. Many of our natural foods are not rich sources of nicotinic acid and diets devoid of meat are likely to be deficient in this factor. Of the cereals, wheat is the best source but like thiamine, about 90 per cent. of the nicotinic acid in the original kernel is lost during the milling process. That is why nicotinic acid or niacin is included as one of the ingredients in enriched flour and bread.

During the period 1938 to 1940 two additional compounds, namely, pyridoxine and calcium pantothenate, were added to the group of B vitamins. The earlier work on pyridoxine depended upon its ability to prevent a dermatitis in rats which was observed during attempts to produce pellagra in rats. Pantothenic acid was recognized as an essential factor in the animal through work with the chick. To-day we know that both of these compounds play an important role in the nutrition of a variety of animals. There is little doubt about the need for these factors in human nutrition although specific diseases have not been associated with their lack in the diet. The reason for this is undoubtedly due to the fact that these two factors are widely distributed in natural foods and that processing of natural foods does not decrease the amount of pyridoxine and pantothenic acid to the same extent that thiamine and niacin are decreased.

Choline is another compound that has been known by biochemists for many years as a constituent of lecithin. Its nutritional significance was not recognized for a long time, but we now know that choline is essential in the diet of the rat, dog and the chick. Clinical work on choline is very limited although recent studies indicate that it may have some value in treating liver cirrhosis.

If rats or dogs are placed on a purified diet consisting of sucrose, casein, a salt mixture and a small amount of fat, together with the pure vitamins discussed thus far, the animals will grow fairly well and reproduce. These results have led some workers to feel that all the known vitamins have been identified. However, there are a number of indications which suggest the existence of other factors. If a little liver or yeast is added to the above ration, an improved rate of growth is obtained. If a bacteriostic agent such as sulfaguanidine is added, the need for additional vitamins can easily be recognized. However, the best evidence comes from work with other animals. If chicks are fed the above ration plus a small amount of purified liver extract the animals develop typi-

cal dermatitis. This dermatitis can be cured by the addition of biotin.

Biotin was first isolated in 1936 and recognized as a growth factor for microorganisms. Later György and du Vigneaud suggested that biotin was identical with the factor which prevented egg white injury in rats. We now know that under normal conditions sufficient biotin is synthesized in the nutritional tract of rats to meet their requirement, but when raw egg white is added to the diet the assimilation of biotin is prevented. In the chick, however, the synthesis does not take place to any appreciable extent and biotin must be supplied preformed in the diet. In order to produce a biotin deficiency in the chick it is necessary to supply a small amount of liver extract in addition to the purified vitamins. If biotin is added to the purified vitamins the factor or factors in the liver extract can be studied. At present these additional factors have not been isolated but one of the factors is undoubtedly related to a factor named folic acid by R. J. Williams which is essential for the growth of lactic acid bacteria. When folic acid can be supplied in pure form it will be possible to study the remaining factors in liver extract and yeast. Thus the chick has proven a very valuable laboratory animal in studies on the newer vitamins.

Work with mice has demonstrated the importance of inositol for the normal development of this animal. Again inositol has been known as a chemical compound for many years, but its specific importance in nutrition was only demonstrated through the use of the mouse. Woolley has shown that inositol may be synthesized in the intestinal tract of the mouse by certain types of bacteria. Thus the requirement of different species for inositol may depend upon the degree to which this synthesis may occur.

Another factor which was first recognized through its effect on bacterial growth and which now shows indication of a vitamin-like action in animals is the rather simple compound, para-aminobenzoic acid. It has been isolated from yeast and is rather widely distributed in natural foods. Ansbacher has shown it to have a slight promotion of growth in chicks and anti-gray hair activity in rats. More recently reports have been made that it has a positive effect on the pigmentation of hair in man. Para-aminobenzoic acid has a specific counteracting effect on the bacteriostatic action of all the sulfa-drugs.

The guinea pig still fails if fed a purified diet containing all the above vitamins. Several natural products must be included in the diet before normal growth is obtained. There is, therefore, ample evidence that we need to continue our search for additional factors.

From this brief summary of the known vitamins it is evident that at the present time the vitamin requirements of man can be expressed in chemical terms to a greater extent than ever before. This fact may lead some individuals to sit back with a sense of security and suggest that nutritional deficiency disease will no longer be a problem in this country. This reaction is, of course, erroneous since we have only made the first step in eliminating nutritional disorders. The synthetic vitamins are merely one set of tools for building a firm and lasting foundation for adequate nutrition for all.

To be sure the synthetic vitamins are of great value to the clinician who must treat extreme cases of vitamin deficiency. It is no wonder that medical workers and the public in general are enthusiastic about the dramatic effects of nicotinic acid in pellagra, thiamine in polyneuritis and related disorders, riboflavin in cheilosis, vitamin K in hemorrhagic conditions, etc. However, the big problem for the medical worker is to learn how

to diagnose deficiencies especially in their early stages when therapy is most valuable. In the last number of "The Milbank Memorial Fund Quarterly" H. D. Kruse summarizes the various manifestations of nicotinic acid and vitamin C deficiencies. More summaries of this kind are needed.

It is the goal of nutrition workers to prevent the development of nutritional disorders. This can only be accomplished by a thorough knowledge of the distribution of the known vitamins in natural foods. The availability of the pure vitamins as standards has given great impetus to extended assays. Work of this kind is slow and tedious, but it is gratifying to find that the industries supplying meat, cereals, milk, fruits and vegetables are giving considerable support to these projects.

Lastly the synthetic vitamins may be used for the fortification of certain foods in order to relieve the wide-spread incidence of a specific vitamin deficiency in restricted areas of this country. This is now possible because of the low cost of some of the vitamins such as thiamine and niacin. It is futile to compare the cost of one vitamin when supplied in the form of a natural food and when supplied in synthetic form because the natural food usually carries an appreciable amount of all the nutrients, not only most of the vitamins, but such comparisons do indicate why it is possible to fortify foods under emergency conditions. For example, 10 mg of nicotinic acid may cost 700 times as much when purchased in the form of high-priced foods as it does when purchased as the pure chemical. In spite of these facts natural foods have been and will continue to be the main source of the vitamin in our diet, but enrichment programs will play their role in buffering sudden changes in the availability of natural foods.

When historians look back on the decade 1930–1940 it will be considered a period when greatest progress was made on the chemistry of vitamins. Let us hope that the decade 1940–1950 will be considered the period when the most sensible application of the available knowledge is made.

A TRUE HUMANIST

We profoundly hope and earnestly strive for a future in which a balanced education may be again possible. What all must see is that such a balance will not be determined by us alone. Our neighbors everywhere on the planet force us to take them into account. Their traditions, their ideas, their possession and probable use of power are among the permanently inescapable forces of life. We can neither wrap ourselves up in the past, and disclaim responsibility for conveying useful truth about the outside world to the coming generation nor neglect the past in our hurry to find solutions for political and social problems too complex to be resolved by simple schemes devised by the philosophers.

From the temple itself comes the assertion that the true humanist is one who is a servant of his times, using his knowledge as "a weapon and an arm not merely a liberal art." Preoccupation with "life and time and eternity" need not exclude consideration of the plainer needs of the hour with their high content of the practical, the scientific and the political. Even in our so-called material civilization science and humanism need never be in conflict among cultivated men. I have no fear whatever that our "culture" will be destroyed by a scientifically implemented war, however prolonged, if we are the victors. My only fear is that the lessons of this war will be lost in the fatigues of a postwar world in which men may again try to find security in provincial simplicities, assumptions and slogans, educational and otherwise. Education must be as intense, imaginative and experimental as the problems of the future are complex and difficult.—*Isaiah Bowman* in the Report of the President, 1941–1942, of the Johns Hopkins University.

STRUCTURE, FUNCTION AND PATTERN IN BIOLOGY AND ANTHROPOLOGY

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THE concepts of the aspects of structure and function are familiar in biology. It is proposed to examine here how far the two concepts can and cannot be applied properly in anthropology.

The terms structure and function are considerably used in anthropology, but with variable meaning. Function especially has been employed in so many and ambiguous senses that some cultural anthropologists, such as Milke, advocate its discontinuance. On the contrary, Linton has attempted to distinguish the form, meaning, use and function of cultural phenomena. Structure sometimes has its common-sense meaning, as when we speak of the structure of a canoe. Sometimes it emphasizes form; sometimes organization; as in the term "social structure" which is tending to replace "social organization," without appearing to add either content or emphasis of meaning.

At bottom, it would seem in biology, when the structures of organisms have been sufficiently analyzed, they fall into certain patterns. These patterns group or classify the organisms; and those showing the same pattern are considered not only similar, but related; that is, connected in descent. In short, one significance of structure is that it yields classification by pattern, which in turn has genetic or "evolutionary" significance; in other words, historical significance. This is of course not the only significance with which biology is concerned: physiological biology is occupied primarily with the direct interrelation of specific structures with specific functions as they exist, without other than incidental attention to how they came to be. However, in historical biology —comparative morphology, systematics, paleontology, partly in genetics—operations are explicitly or implicitly in terms of basic patterns that have historical depth.

Thus the mammalian pattern of dentition is 44 teeth: 3 incisors, 1 canine, 4 premolars, 3 molars on each side of each jaw; and this pattern—though it may be reduced and greatly modified by specialization of shape—is not violated except in the case of ancient lines of organisms, like the whales, whose total structure, as well as total functioning, is highly modified. The vertebrate pattern, at any rate above the fishes, provides for a pair of limbs at each end of the trunk. When an altered function is achieved, like flying, it is by conversion of a pair of legs into wings. In the bats and certain ancient reptiles, the flying surface of the wing is supported by a specialization of digital structure. In the birds and certain other extinct Reptilia, the wing is supported on the proximal heavy bones of the limb, with loss of its digital portions. But in no case has a vertebrate achieved flight except by functional—and structural—conversion of one of the pairs of limbs generally and presumably originally serving terrestrial or water locomotion. This is in contrast to the insects, whose basic pattern includes three thoracic segments, each provided with a pair of jointed legs and two of them with wings also. An insect accordingly flies without giving up any of its legs by conversion. Deep-seated as this insect pat-

tern is—and it has geological antiquity—it is not absolutely basic. The other arthropods are wingless but possess more than six legs in their patterns: spiders eight, crabs ten, other crustaceans, scorpions and centipedes more yet; but always with one pair only per segment. The insect pattern, therefore, represents an important modification of a still more ancestral pattern.

The idea of basic pattern has not been wanting in anthropology. Sapir articulated it most clearly. Language is the part of culture which particularly lends itself to pattern recognition, because its precision of form facilitates analysis. However, as a concept or tool, basic pattern has been used much less, and has been formulated less clearly, in anthropology than in biology. One reason is that in culture the tremendously conservative force of organic heredity is not operative; at any rate, is obviously not the direct or immediately operative factor. Cultural patterns therefore tend to be short-lived: we may trace them for a few thousand years, but not for many millions. Moreover, widely divergent cultures can and do hybridize; organisms, only within very narrow limits of relationship and descent. There is nothing in the biologic realm comparable to the fusion of Helleno-Roman and Asiatic civilizations to produce Christian civilizations; or of Sino-Japanese and Occidental culture in Japan since 1868. The tree of life is eternally branching, and never doing anything fundamental but branching, except for the dying away of branches. The tree of human history, on the contrary, is constantly branching and at the same time having its branches grow together again. Its plan is therefore much more complex and difficult to trace. Even its basic patterns can in some degree blend; which is contrary to all experience in the merely organic realm, where patterns are irreversible in proportion as they are fundamental.

However, granted the relative mutability, plasticity and ultimate fusibility of all patterns in human history, there remains no doubt that there are cultural patterns which are more basic or primary and on the whole older, and others which are more superficial, secondary and transitory. Obviously, if we wish to trace the history of human civilization—especially in its preliterate and therefore prehistoric phases—it is of the utmost importance to recognize the basic patterns and distinguish them from their secondary modifications. The older anthropology, it seems to me—Tylor for instance—made a deliberate attempt to do this. It failed, to a large extent at least, because of several related deficiencies. It tended to substitute common denominator for true pattern. It synthesized prematurely into formulations like animism and magic and totem, which are part basic pattern indeed, but in part only denominator. And, finally, it forgot that all recorded history being a series of objectively unique events whose major significance lies in their organization into distinctive patterns and not in ill-defined formulas or generalized denominations—it forgot that very probably the same held of the prehistoric and primitive part of the human story. True, we also use the word "formula" for mammalian dentition. But the mammalian dentition formula is quantitative; it is entirely precise; it is highly distinctive, in fact unique; and it has, so far as the totality of our knowledge allows us to judge, authentic historical depth and significance. In contrast, a formulation like animism or totem has none of these qualities, except historical depth, and this may prove to be an accidental denominator; even the historical significance is none too sure, especially for the totem. Whereas the relatively mutable patterns of culture are more difficult to extricate than the relatively stable ones of life, the earlier anthropology, even

though headed in a sound direction, made a premature, superficial synthesis —perhaps precisely because of its immaturity as a branch of study.

The need of more exact and deeper analysis was recognized in the next stage of our science; but with it, the synthetic impulses faded. A healthy distrust grew up for the hazy formulations of the earlier generation. If we now used them, it was of necessity; they were crutches, no longer goals. We reveled in discovering the rich diversity of forms which culture assumed. We analyzed as carefully as any historian; but we refrained, for a time, from doing any history, from probing for time depth and relative sequences. We had become shy of the sort of findings which our predecessors considered historical, or an equivalent of historical findings; but we had not yet attained to the concept of the basic pattern as a tool which inevitably carries at least historical implication, if not outright significance.

In the present stage of anthropology, two currents are flowing in opposite directions. First, there is a resumption of historic interest: analysis is continued from the preceding stage, but it is more courageously being used for constructive historical objectives, with increasing recognition of the value of the basic pattern method. It is important to remember that this approach is not wholly phenomenological and undynamic. After all, as a pattern is basic, it is determinative of its modifications: it sets the frame within which change can take place; it is one of the factors which jointly produce what happens. The charge sometimes leveled that history is only a series of facts, unorganized but for their time order and meaningless except in themselves, proves only one thing: that those who so hold have, through over-preoccupation with other interests, a blind spot for the historic approach, whether in biology or in human affairs, and fail to recognize the significances which inevitably attach to pattern organizations.

The other current in contemporary anthropology aims at a sort of physiology of culture and society. It is concerned with extricating process, with uncovering dynamics. It comprises those who accept the name of functionalist, and the like-minded who insist on working with present-day phenomena and have little concern with the past. They hope to move from the contemporary directly into generalization, perhaps into universals. It is true that knowledge of living phenomena is inevitably capable of being fuller than knowledge of former ones. A physiology of cultural and social phenomena is presumably possible and would certainly be extremely important. The danger is in confusing a goal with an attainment. And to be ambiguous on this distinction is specially tempting to those unduly interested, for scientists, in personal success. The public at large is unaware of the fact that in biologic physiology selective experiment with control is the essence of method, but that in social physiology it is selection alone that is chiefly possible, both experiment and control being as yet scarcely devised, if devisable at all. Also, with the focussing on the living, time perspective goes out; and, with this, the best opportunity of recognizing the fundamental patterns involved. In fact, it would appear that the area of which there is immediate consciousness in cultural and social change is the special modifications which are taking place at the moment, while consciousness of the more enduring and basic structural features tends to be lost sight of—both by those desiring to bring about change and those interested in studying it. It is accordingly no accident that Malinowski avowed an antihistorical bias; that Radcliffe-Brown admits the historical approach but confines it to documented data and cites as

his exemplars of historical anthropology chiefly the precursors of Tylor; and that Warner avoids a quarrel but actually considers only recent antecedents, and those mainly in order to heighten background contrast.

All the functionalists put unusual emphasis on integration. Either this amounts to making explicit what has always been taken for granted, or, when most rabid, it comes to elevating integration into a final principle which explains everything and thereby chokes off farther inquiry. It is very much as if physiologists were to proclaim as their ultimate finding: see how the human body hangs together! See how harmoniously it works!

There is of course no valid quarrel with a primary interest in function in the socio-cultural field, provided such interest is not stretched into a superiority dogma or panacea. It is as one-sided, and ultimately sterile, to be exclusively preoccupied with structure as with function. This has been long since learned in biology, and will have to be learned in anthropology.

One concept shared by biology and anthropology is that of convergence. For instance, the pseudo-vertebrate eye, beak, and backbone of the molluscan squid. Trees, and again vines, have over and over originated independently in separate families of plants; so has the habit of male and female sex-organs being borne separately—alternatively—by different plant individuals. Snakes move like worms, and whales swim like fishes. Flight has been attained separately by insects, reptiles, birds and the mammalian bats, not to mention man, if we transcend the organic level. Almost exactly parallel socialization has been attained by the termites, who are descended from the roach stem, and by the ants who are Hymenoptera. There are thousands of instances, some of them highly special, like the horny forehead shields with which access to the burrow is blocked both by some toads and by some termite warrior castes.

Now what is characteristic of all organic true convergences is that they are analogues, not homologues. There is a similarity of function, but a dissimilarity of structure. The dissimilarity is usual even in the converged organ or organs, invariably present in the total structure of the organisms. In short, it is because the basic patterns differ that the similarity is convergent. The histories are unlike, the secondary results are like; especially as regards function, use, and behavior; though the like results need not be superficial or trivial—in fact may be accompanied by pervasive modifications of the organism.

While we have long recognized convergence in anthropology, we have tended to deal chiefly with limited, specific cases in which reasonable proof was not too difficult to bring. Probably we have been too unsure of fundamental pattern structure in the protean field of human history to venture to class larger phenomena, corresponding to arboreal habitus, flying, crawling, socialization, either as convergences or as historic pattern persistences. This is certainly a matter in which anthropology is backward. But it is clear that progress can ensue only in the degree that we learn to dissociate patterns into basic and derivative or modificatory ones. This is obviously going to be harder in the field of culture than it has been in biology; but precedent should at least encourage the attempt.

One fact may help. Organic convergences not only always involve function strongly, but their similarities are easily recognized; lay observation, commonsense observation suffice to recognize trees, flight, socialization, and the like. This suggests that long recognized, frequently recurring phenomena of culture are likely to be the ones among which our

broad convergences are to be found. As examples might be mentioned the clan, totem, cross-cousin marriage, the mother-in-law taboo, potlatch, feudalism. As regards several of these, multiple causations and origins have for some time been advocated on specific associational grounds. Other possible examples are taboo, sacrifice, kingship, urbanization, writing, navigation, secret societies.

As a boy I got hold of a popular natural history, probably reprinted from an original several generations old, which classified animals into Schalthiere, such as clams, lobsters, turtles, and armadillos; Kriech-thiere which included worms and snakes; and so on. The wonder is that such a work was still in circulation to come into the home and hands of anyone born in the last quarter of the nineteenth century. The classification is logical, naïve, and essentially functional. Shells, it is true, are nominally structural, but their real likeness is confined to their protective and defensive function. Function, apparently, is what the pre-scientific mind first takes hold of. Analysis into structure comes later, because its implications, its resultant significances, are not readily visible: it tends to pass as aimless antiquarian idling.

Now we have done enough analysis in anthropology to have good reason to believe that the recurrent phenomena which we loosely call feudalism, clans, cross-cousin marriage, etc., have polygenetic origins; and therewith the inference is near that they are merely derivative and not basic patterns. It seems that we might do well to avow this inference more explicitly; and at the same time search more rigorously for patterns that are basic. This is not as easy as in biology, where we can at least begin by laying a specimen on the table and cutting into it with a knife, and then bringing up the microscope and reagents when needed. If our search were as simple as that, anthropologists would have got farther than they have. But, granted the difficulties, have we nevertheless tried as wholeheartedly as we might?

Two endeavors are indispensable in such search for basic patterns: analysis and comparison. Analyses we do sufficiently well. For some forty or fifty years there has been produced an increasing number of monographic, analytic studies of tribal cultures, sufficiently detailed in many cases, not always inspirational, but mostly competent and useful. It is in comparison that we hang back; perhaps in undue fear that all broadly comparative work will suffer the stigma of the old comparisons which were designed to discover universals. When modern anthropologists make comparative studies over a wide range, these tend to be limited to items, such as the spear-thrower or oil lamps, rather than to whole cultures or systems. In all this, there is manifest a lack of courage about attacking problems that could be labelled constructively historical. But are we going to be deterred forever because there have been simplistic speculators who constructed pseudo-histories?

One criterion will help. With a valid basic pattern, its various manifestations show a point-for-point correspondence. Not that every mammal must have 44 teeth of four shapes; but such teeth as it has must correspond to particular ones of the 44; and once they do, the greater their modification from the general or original shape—like the elephant's incisor tusks and successive molars—the more interesting are their fit, adaptation, and history. In comparative linguistics, indeed, which is historical linguistics, such as Indo-European, Semitic, Bantu, this insistence on point-for-point correspondence has successfully become a cardinal principle of method. Culture history is no doubt more difficult; but there is every reason to believe that the principle applies.

Perhaps it is time that I cite some

examples of basic patterns in culture. They are of course surest where cultures have been documented for a considerable period. Hebrew-Christian-Mohammedan monotheism seems a good illustration; and a rich one, if we remember all its diversifications into religions, churches and sects. We know that the three "religions" are historically connected: they are outgrowths of one another. We can also define the pattern: a single deity of illimitable power, excluding all others except avowed derivatives, and proclaimed by a particular human vessel inspired by the deity. If we contrast with this the supreme deities of other religions, philosophical and primitive, we find them invariably lacking one or more of the characterizing features—usually all three. These other supreme deities, accordingly, are analogous convergences only.

Another example is the alphabet, as set off from other methods of writing. All alphabetic writing—that is, graphic symbols denoting the smallest acoustic elements of speech, but no symbols of other kind—has spread from a single origin in Western Asia about three thousand years ago. And there is point-for-point correspondence in all the manifold varieties of alphabets. Aleph, beth, gimel, daleth, correspond to alpha, beta, gamma, delta, and to A, B, C, D. Where there are changes of shape of letter, or of its sound value, or its position, these can be accounted for, at least in the overwhelming majority of cases, and lead us back to the original pattern. For instance, we know why, how, and when C came to replace G as the third letter in our own form of alphabet, and W was added.

Such a pattern, or our monotheistic one, is really a system which extends across cultures, and not a culture itself. It is possible that the same will hold true generally for all associations or complexes of cultural phenomena which fall into basic patterns. They represent pure inventions, or a series of inventions, corresponding more or less to mutations or series of mutations in organic nature. The word mutation is here used not in any specific sense which it may have in genetics with reference to a particular mechanism but as a generic label to indicate any radical, drastic, or significant change in hereditary type.

By contrast, systems of writing like the Egyptian, Cuneiform, Chinese do not share any point-for-point correspondence either with the alphabet or with one another: neither in the shape, value, nor order of their characters. So far as they are similar—in being pictographic and ideographic and syllabic—they are alike only in general function, not in specific structure; and they represent analogical convergences. What they have in common, such as the tendency to represent the sounds of speech by a sort of punning—the rebus method—and the tendency to deal with syllables rather than elemental sounds, is due presumably to psychological factors of the human inherited constitution, and therefore really outside the level of culture as such. Just so, certain generic features common to organisms which share say an arboreal habitus, or a swimming or flying one, are conditioned by mechanical factors to which the organisms adapt themselves.

When it comes to the material or technological aspects of culture, physico-chemical factors similarly impinge on culture. That bronze is composed of copper and tin, and that it is harder and casts better than either metal alone, are physico-chemical facts. Consequently, the mere fact that ancient Mesopotamia, China, and Peru made bronze is of no relevance to the problem of whether their bronze arts belong to the same or different patterns; that is, whether they are genetically connected or separated. That must be determined from specific cultural features, such as non-compul-

sory techniques in the metallurgical process, the forms cast, and the like. With these features considered, it becomes highly probable that Mesopotamian bronze and Chinese bronze are slightly variant manifestations of one pattern, but ancient Peruvian bronze represents a separate pattern and origin. For instance, Mesopotamia and China used bronze for swords and for ritual vases or other vessels; Peru did not.

Plow agriculture constitutes another example of a basic pattern. This pattern comprises at least three essential features: the plow itself; animals to draw it, which of course must be domesticated; and food plants of such a nature, like barley, wheat, millet, that they can be profitably grown only by broadcast sowing, which in turn involves fields of at least fair size, as compared with gardens. Still other features have become associated, such as the use of the dung of the animals as fertilizer. The plow is generally considered to have been an unrepeated invention, whose precise time, place, and circumstances we do not know, though it took place in the last Stone Age and probably in or near southwestern Asia, and spread along with cattle, with barley and associated plants, and usually with manuring, to all those parts of Europe, Asia, and Africa in which it was used in 1500. Native America also evolved a highly developed system of agriculture on which we of to-day have drawn for important loans. But native American agriculture belonged to a radically different pattern. It did not know the plow. It did not use draft animals, though it had domesticated ones like the llama. It did not sow broadcast but planted by hand and cultivated in hillocks. It totally lacked wheat, barley and their associates, substituting for them a series of others of which maize was the most wide-spread and principal. And it either did not fertilize at all or it used fish. It has therefore long been the conclusion of conservative, non-speculative students that New World agriculture had an origin and a history entirely separate at least from Old World plow agriculture. In short, we have two patterns and two histories.

Agriculture as such I would not call a pattern, but rather a common denominator. Numerous primitive peoples in Africa, Asia and Oceania farmed, planting with hoes or digging-sticks, without using associated animals, and raising root-crops, fruits, and even some cereals like rice or sorghum. We are not able to affirm whether all this farming or gardening had a single origin or several. It is probable that plow agriculture represents an "invention-mutation" added to some phase or other of this more primitive gardening. But we cannot say at present to which phase, any more than we know whether the phases were historically connected or independent developments. In brief, plow agriculture is a specific phenomenon, or set of associated phenomena, like mammalian dentition; whereas agriculture is rather a generalization, or concept, logically definable indeed, but rather too vague, variable or amorphous to serve as a solid foundation for a scientific structure; just as concepts like shellfish or arboreal habitus or aereal locomotion have proved unserviceable for primary scientific classification.

A given trait may form a critical part of a pattern in one situation, but have low pattern value in others. Teeth, for instance, have less diagnostic and classificatory significance in the lower vertebrates and invertebrates than in the mammals. The same holds in the field of culture; for instance as regards "dichotomized" social structure or moiety organization. In native Australia moieties are almost universal, and in New Guinea and Melanesia they are frequent. They basically determine marriage and descent; whom one may not marry, whom

one must marry. In Australia there is redichotomization into four sections, and even re-redichotomization into eight subsections. Related to this plan is the fact that all human beings with whom one has dealings are considered kin—are made into kin, if necessary—and put into one or the other moiety. This whole organization, often very elaborate, is superimposed on one of another type; the small local horde, autonomous and owning a territory, all its members interrelated through male descent, and therefore unable to marry horde members. The two plans of organization do not conflict but supplement each other. The moiety is international, as the native sees it, and therefore makes for successful amities and bonds outside, while not interfering with the subsistential and familial solidarity of the horde. This Australian scheme is very distinctive—infinitely varied in minor detail, but remarkably constant in underlying pattern.

Now moieties occur also in all other continents, but sporadically, by contrast. They occur often among peoples who are not living in hordes, and who do not insist on classifying everyone as a kinsman. Sometimes they are exogamous, occasionally endogamous, sometimes not connected with marriage or descent at all, but with ritual or games or government. All these other social dichotomizations in Asia, Africa and the Americas do not reduce to a consistent pattern; and their geographical distribution is tantalizingly spotty, instead of continuous. They are therefore justly regarded as having had a number of origins, separate in circumstances as well as in time and place, and with separate and different growths. Such similarities as they present, to one another and to Australian moieties, are therefore superficial and of the order of convergences.

There may well be in the nature of the human mind a deeply implanted tendency to construe and organize its world in terms of duality, bipolarity, and dichotomization, and this inclination may lie at the root of all moieties, in Australia and elsewhere. But even if there exists such a tendency, it is a psychological fact. It is only a condition of culture, not a phenomenon of it. On the cultural level, there remains the difference that in the Australian area the psychological trend toward dichotomization has been channeled into consistent, wide-spread, influential and probably ancient expression in a pattern of social structure, but elsewhere the same trend has entered only into local, intermittent, and secondary patterns.

These examples from the religious, intellectual, technological, economic and social fields may suffice to illustrate what is meant by fundamental patterns of culture. It is clear that they are something different from Benedict's "Patterns of Culture." These latter are psychological orientations of societies comparable to personality orientations or attitudes, such as paranoid, megalomanic, Apollonian, etc. When strongly developed, they are also influential, but selectively, and on the slant of a given culture, whereas the basic patterns here discussed operate constructively and often cross-culturally. In the Benedict approach, a pattern is a psychic constellation molding the typical personality of a society by imparting a certain warp to that society's culture. The basic patterns referred to in the present essay are the more pervasive and permanent forms assumed by cultural content, and tend to spread from one society and culture to others. In short, basic patterns are nexuses of culture traits which have assumed a definite and coherent structure, which function successfully, and which acquire major historic weight and persistence.

Returning to the biological analogy,

we must distinguish where the pattern parallel holds and where it does not hold. A particular culture is not comparable to a species, even though the members of any one society are given, by their common culture, a certain likeness of behavior somewhat comparable outwardly to the likeness of the members of one species. (The mechanisms which produce the likeness are of course quite different.) A culture is always, so far as we can judge, highly composite in the origin of its constituent materials. As I have said before, the branches of the tree of human culture are always growing together again. It is a commonplace that in our American civilization we speak a Germanic language shaped in England with the absorption of a larger Latin content, have a Palestinian religion, eat bread and meat of plants and animals probably first domesticated in or near Western Asia with additions from tropical America, drink coffee from Abyssinia and tea from China, write and read these words with letters originating in Phoenicia, added to in Greece, given their present shape in Rome, and first printed in Germany; and so on. There is no reason to believe that any living culture is less intricately hybrid. Therewith the analogy between cultures and species breaks down. Rather, it is ecological aggregates to which cultures can be compared: local associations of species of diverse origin. Certainly the larger faunal and floral regions, like the Palaearctic, Neotropical, Indo-Oriental, Ethiopian, Australo-Papuan, correspond strikingly, even in part to geographic coincidence, with the generally accepted major cultural regions; and there are parallels in retardation, specialization, and expansive productivity of new forms.

All this suggests that the nearest counterpart of the organic species in the field of culture is the culture trait and not the culture entity or culture. It is the species that is repetitive in its individuals; the trait that is repetitive in its exemplars—in the thousands of automobiles or stone axes manufactured according to one model or form, in the word or grammatical construction that is uttered over and over again. It is related species or genera or families or orders, that have persistent structural patterns in common; and it is among the traits that belong to one field of culture—such as writing, belief in deities, agriculture—that the persistent fundamental patterns of culture grow up. It would be easy to stretch the analogy too far; but within due limits it would seem to have utility in stimulating reflective inquiry, especially as regards the historical aspects of organic and super-organic phenomena.

THEY GAVE LIFE TO BONES

By CLAYTON HOAGLAND

EDITORIAL DEPARTMENT, *The Sun,* NEW YORK CITY

There lived in Philadelphia just a century ago a small boy whose interest in nature and science developed when he was very young. It was expressed in notes and drawings in his journal, and in little sketches he made to illustrate his letters with pictures of birds and reptiles. One day in 1846, when this boy was not yet seven, he was brought to a natural history museum that had been founded by Charles Willson Peale, soldier in the Revolutionary War and portrait painter. There the boy saw the mounted skeleton of an Eocene sea monster, the Zeuglodon. It is easy to imagine his awe as he beheld this exhibit, for it consisted of the bones of several skeletons strung together to the grotesque length of 114 feet!

Years later, when Edward Drinker Cope had become one of the foremost American paleontologists, the memory of this skeleton may well have amused him. As he had a lively imagination to the end of his days, the boyhood fancies aroused by sight of the monster he saw in the museum must have been wonderful indeed. Now, Cope's imagination was of the greatest value to paleontology. By using it he blew more than a breath of life into restorations of dinosaurs and other ancient creatures that were first arousing a great deal of public interest half a century ago. Before Cope died in 1897 he told a journalist friend, William H. Ballou, and the animal artist, Charles R. Knight, his conclusions as to the movements and habits of various Mesozoic animals over whose fossil remains he had spent years of exacting study.

We shall return to what Cope did for vertebrate paleontology, but it is well to recall here that his life spanned a period which began in the childhood of American fossil collecting, and which reached its peak in the early years of the twentieth century. By then a vast amount of knowledge had been organized, a number of amazing fossil skeletons had been found. It was by then possible for artists to model and to picture numerous extinct creatures realistically. By means of well-designed museum exhibits, and through books illustrated by Charles Knight, R. Bruce Horsfall, Erwin S. Christman and a few others, the public has learned to think of the great saurians, and other ancient reptiles and mammals, as *living* creatures, rather than as so many bones wired together and mounted on platforms, or in glass cases. The story of that difficult art is interwoven with the chronicle of fossil hunting in the United States for more than seventy-five years.[1]

What Cope, Joseph Leidy and O. C. Marsh did for paleontology was, as we know, pioneering, for these three established the science in America. Blundering efforts made in the years before they lived had advanced paleontology in this country only very slowly. Until well into the nineteenth century little was accomplished in finding and restoring fossil animals here. Few men seemed any more enlightened than in the days

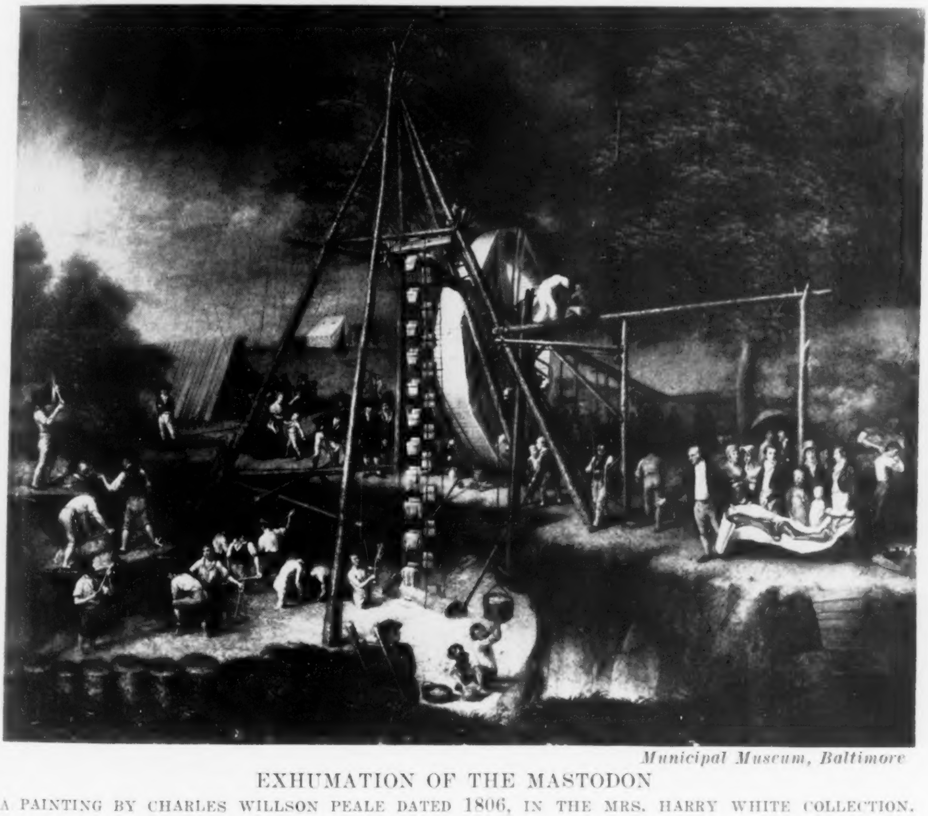
[1] For valuable advice on collecting material for this article the author is grateful to Dr. George Pinkley, associate curator of comparative anatomy of the American Museum of Natural History; for information on Mr. Knight and Mr. Christman he acknowledges the help of Mr. Knight himself, of the late Dr. Walter Granger of the American Museum of Natural History, and of Erwin H. Christman, son of the artist. Mr. Horsfall and Mr. Allen were cooperative in providing information on their work.

when a discovery of the bones of a big vertebrate appeared to confirm the belief that human giants once lived on earth.

Among the most remarkable of all the early attempts to promote scientific interest in fossil creatures was that museum in Philadelphia visited by the boy Cope. He saw it fifty years after it had been established by Charles Willson Peale. When Peale had been a successful portrait painter for twenty years he installed in a large room in his house fossils he had collected, and various natural specimens he had received from friends. This collection was later moved to a hall in the building occupied by the Philosophical Society, and in 1802 moved to the State House, which had been vacated by the Legislature. The first board of directors of this museum, as formed in 1792, included Alexander Hamilton, James Madison and Robert Morris. One of the active members of the institution was George Washington.[2] It is important in our story, for there apparently it was that art and paleontology in America were first married.

The elder Peale sensed to an extraordinary degree the need for public instruction in natural history. He was the first American artist who was successful in catching popular interest in authentic

[2] "Peale's Museum" by Harold Sellers Colton. *Popular Science*, September, 1909.



Municipal Museum, Baltimore

EXHUMATION OF THE MASTODON

A PAINTING BY CHARLES WILLSON PEALE DATED 1806, IN THE MRS. HARRY WHITE COLLECTION. THIS ARTIST, A SOLDIER AND SCIENTIST, EXCAVATED FROM PEAT BOGS NEAR NEWBURGH, NEW YORK, BONES FROM WHICH HE RECONSTRUCTED TWO SKELETONS. IN AN ACCOUNT OF THE FIND HIS SON REMBRANDT WROTE: "TWENTY-FIVE HANDS, AT HIGH WAGES, WERE ALMOST CONSTANTLY EMPLOYED AT WORK SO UNCOMFORTABLE AND SEVERE, THAT NOTHING BUT THEIR ANXIETY TO SEE THE HEAD, AND PARTICULARLY THE UNDER JAW, COULD HAVE KEPT UP THEIR RESOLUTION."

Peabody Museum

CRETACEOUS TOOTHED BIRD

A DRAWING BY FREDERICK BERGER, REPRESENTING ONE OF O. C. MARSH'S MOST FAMOUS RESTORATIONS, PUBLISHED IN THE EARLY 1880'S. THE BIRD STOOD LESS THAN A FOOT HIGH.

restorations of fossil animals. It seems likely he was among the first to think of exhibiting natural history specimens before correctly painted landscapes and in appropriate foregrounds. For the mounted quadrupeds in his museum he carved wooden skeletons, over which skin could be stretched—"a stupendous labor," he wrote, "originating from and affected by an enthusiastic desire of exhibiting a series of real forms as they exist in nature. . . ."

Peale went so far as to display paintings in the hall where he mounted the skeleton of a mastodon. This fossil he and his son Rembrandt had uncovered in 1801, at considerable cost, from marl pits near Newburgh, New York. Writing of the exhibit, Rembrandt Peale—erroneously describing it as the remains of a mammoth—told how two complete skeletons had been fashioned from the excavated bones of three animals. "Nothing is imaginary," he wrote, "and what we do not unquestionably know we leave deficient."

In the Municipal Museum of Baltimore is a painting by Peale, done in 1806, of the scene of the excavation for the mastodon bones. It depicts a huge pump drawing water from the pit, and among the throng on the brink stand Peale and his son, holding a large drawing of certain bones already uncovered. The elder Peale died in 1827. His museum survived another nineteen years; shortly after little Edward Cope's visit to it in 1846 the institution was closed for lack of support, and its collections were sold at auction.

Bettman Archive

MODEL ROOM, CRYSTAL PALACE

IN THIS LONDON WORKSHOP IN THE EARLY 1850'S WATERHOUSE HAWKINS FASHIONED, LARGELY FROM IMAGINATION, MONSTROUS RESTORATIONS OF VARIOUS PREHISTORIC REPTILES IN "LIVING" ATTITUDES. THIS PICTURE APPEARED IN THE *Illustrated London News*.

About 1840, the year Cope was born, another Philadelphian, also destined to become an outstanding American scientist, entered the University of Pennsylvania. Joseph Leidy had studied art and had painted signs for a livelihood before he turned to medicine, anatomy and paleontology. His treatise "On the Fossil Horse of America" was published when he was but twenty-four. Osborn wrote of him:[3]

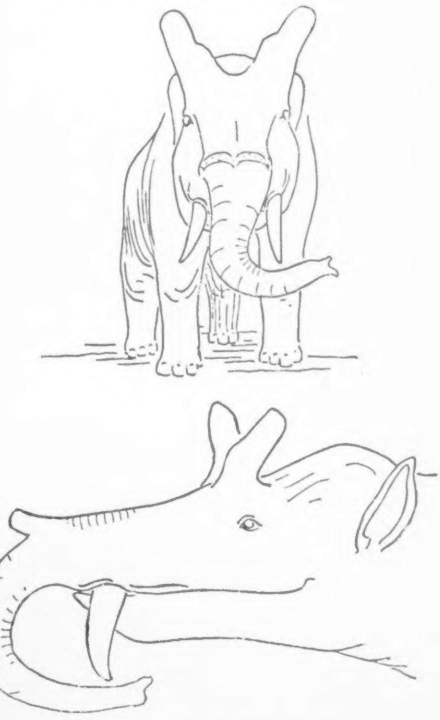
> Twelve years before Darwin brought forth the "Origin of Species" this young man was beginning to assemble a mass of data which would have been of value to the great British naturalist. As shown by Professor Scott, [William Berryman Scott] he was tracing the ancestral lineage of the horse, the camel, the rhinoceros, the tapir family, the titanotheres, and last, but not least, the anatomical forebears of man.

Peabody Museum

EARLY RESTORATIONS

A SKETCH OF A SMALL DINOSAUR AND OF WINGED AND MARINE REPTILES, PAINTED ABOUT SIXTY YEARS AGO BY ARTHUR LAKES, AMATEUR PALEONTOLOGIST AND ASSISTANT TO MARSH IN THE FIELD AND AT YALE UNIVERSITY. ("O. C. MARSH: PIONEER IN PALEONTOLOGY," C. SCHUCHERT AND C. M. LE VENE. YALE UNIVERSITY PRESS.)

[3] "Impressions of Great Naturalists," by Henry Fairfield Osborn, Scribner's, 1924.



COPE'S "DAWN EMPEROR"

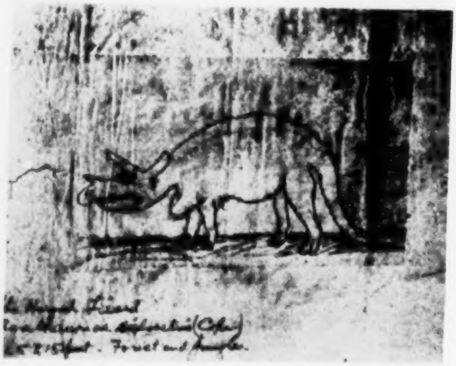
A SKETCH FROM A LETTER BY EDWARD DRINKER COPE, DATED JANUARY 12, 1873, OF THE EOBASILEUS OF WYOMING, WHICH HE THEN DESCRIBED AS A PROBOSCIDEAN. OF THE UPPER SKETCH HE WROTE THAT THE CREATURE "WALKED WITH THE KNEE FAR BELOW THE BODY AS ELEPHANTS DO," AND THAT "THE HORNS AND HEAD ARE RATHER TOO LARGE." ("COPE: MASTER NATURALIST" BY HENRY FAIRFIELD OSBORN. PRINCETON UNIVERSITY PRESS.)

It was Dr. Leidy who described in exact detail the chelonian and mammalian fossils from Wisconsin, Iowa and Wyoming collected in the 1840's by Dr. Hiram Prout and David Owen. Leidy's research produced great blocks of those basic data on which the artists working for paleontology have devised realistic paintings and sculptures of prehistoric animals.

The science long remained a mystery to the public, however. In 1869 appeared Leidy's master work on the extinct mammalian fauna of North Dakota and Nebraska; yet not for another quarter of a century was any successful at-

tempt made to translate into truly life-like pictures and popular accounts the information compiled during the busy period of fossil hunting that began in Leidy's time.

In England, however, something was done, about 1854, that amused a few paleontologists while it probably enraged others. Waterhouse Hawkins, a sculptor, made models of several prehistoric creatures for an exhibit in the Crystal Palace in London. Authentic restorations were then scarce, for few complete skeletons had been found, so this sculptor let his imagination be carried away by images evoked by the names of the animals.[4] Working on a scale he believed to be life size, he depicted a Megalobatrachus as a giant frog, and modeled a Trachodon with a head like a huge iguana.



CRETACEOUS "HORNED LIZARD"
A PENCIL SKETCH BY COPE OF A PAIR-HORNED CERATOPSIAN IS INSCRIBED "THE HORNED LIZARD AGATHAUMUS SILVESTRIS (COPE) 25 × 15 FEET. FOREST AND JUNGLE." ("COPE: MASTER NATURALIST" BY HENRY FAIRFIELD OSBORN. PRINCETON UNIVERSITY PRESS.)

When O. C. Marsh, the paleontologist, saw these models in 1895 he wrote of them: "The dinosaurs seem . . . to have suffered much from both their enemies and their friends. Many of them were destroyed and dismembered long ago by their natural enemies, but, more recently, their friends have done them further injustice in putting together their scattered remains and restoring them to supposed life-like forms. . . . So far as I can judge, there is nothing like unto them in the heavens, or on the earth, or in the waters under the earth. . . ."[5]

Twenty years after Hawkins had modeled his monsters for London he was invited to do sculptures for the celebration in Philadelphia of the centenary of the Declaration of Independence. The secretary of the Smithsonian Institution sought Marsh's opinion of the project. That eminent scientist replied by letter in December, 1875, and this is what he wrote:

> I do not believe it possible at present to make restorations of any of the more important extinct animals of this country that will be of real value to science, or to the public. In a few cases where the material exists for a restoration of the skeleton alone, these materials have not yet been worked out with sufficient care to make such a restoration perfectly satisfactory, and to go beyond this would in my judgment almost certainly end in serious mistakes. Where the skeleton, etc., is only partially known the danger of error is of course much greater, and I think it would be very unwise to attempt restoration, as error in a case of this kind is very difficult to eradicate from the public mind, *e.g.*, the old restoration of Labyrinthodon (with frog-like body) still continues to appear in popular scientific books. . . . A few years hence we shall certainly have the material for some good restorations of our wonderful extinct animals, but the time is not yet.[6]

The prediction which closes this letter was fulfilled, as we know. But danger of error did not deter those in Philadelphia in 1875 who were sold on the Hawkins sculptures. That ambitious artist did finally make a plaster model of Cope's dinosaur Hadrosaurus for the Exposition. The secretary of the Smithsonian later was able to watch this dis-

[4] "Man and His Creations," by F. A. Lucas, *Natural History*, Vol. xxvi, May–June, 1926.

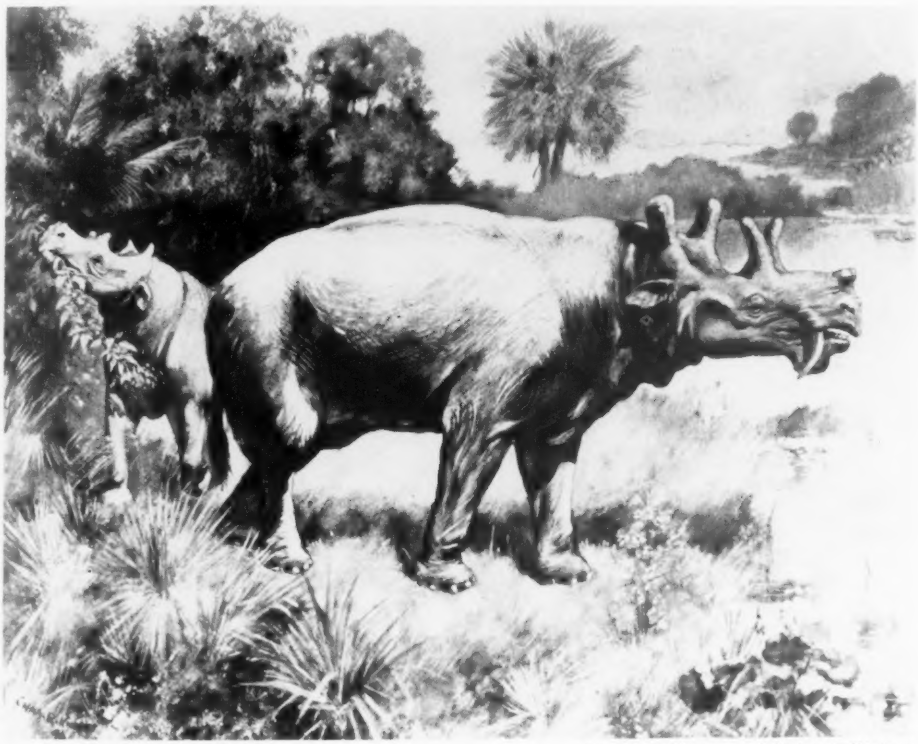
[5] "O. C. Marsh: Pioneer in Paleontology," by Charles Schuchert and Clara M. Le Vene; Yale University Press, 1940.

[6] *Op. cit.*, (Schuchert and Le Vene's "O. C. Marsh").

American Museum of Natural History

TRAPPED IN THE TAR POOLS

THE MURAL BY KNIGHT DEPICTS ACCURATELY THE STRUGGLES OF PREHISTORIC CREATURES CAUGHT IN THE RANCHO-LA-BREA PITCH POOLS OF LOS ANGELES, CALIFORNIA. A SABER-TOOTH TIGER HERE ATTACKS THREE GIANT GROUND SLOTHS (MEGATHERIUM). THE PAINTING ADORNS A WALL OF THE AMERICAN MUSEUM OF NATURAL HISTORY.



American Museum of Natural History

UINTATHERIUM BROUGHT TO LIFE

THIS PICTURE BY CHARLES R. KNIGHT PAINTED IN 1896 WAS ONE OF THE FIRST AUTHENTIC RECONSTRUCTIONS OF THIS EOCENE MAMMAL, WHOSE HABITS AND FORM WERE NOT THEN WELL-KNOWN. THE ARTIST USUALLY MADE SMALL WAX MODELS FROM ARTICULATED SKELETONS AND PLACED THEM IN SUNLIGHT TO OBTAIN THIRD-DIMENSION IN PAINTINGS.

© *Field Museum of Natural History*

CRETACEOUS REPTILES OF THE SEA

A MOSASAUR SKELETON TWENTY-NINE FEET LONG, FOUND IN KANSAS, WAS DESCRIBED BY OSBORN AND ILLUSTRATED BY KNIGHT IN *Science* IN DECEMBER, 1899. THIS MURAL SHOWING A MOSASAUR ATTACK ON ARCHELON (PTERANODONS FLYING ABOVE) WAS PAINTED THIRTY YEARS LATER.

integrate on its base outside the National Museum under the assaults of more than a decade of Washington weather.

Of course, the progress of fossil restoration has since shown the soundness of Marsh's opinion. His dourness, his suspicion of anything pseudo-scientific, was fitting in a temperament that earned for him at the Century Club the nickname of "the great dismal swamp." He was more than the head of the division of vertebrate paleontology of the U. S. Geological Survey—more than the distinguished professor of Yale; he became leader in the art of making lifelike restorations of the skeletal remains of toothed birds, swimming and flying reptiles and other extinct creatures of the earth. When the Peabody Museum in 1876 exhibited part of Marsh's collection of vertebrates, there was shown a papier-maché model of the dinoceras Mirabile, constructed from remains found in Wyoming.

It was about that time that the dinosaurs were attracting international attention. Many have doubtless heard of the long and bitter rivalry of Marsh and Cope. It lasted through a period when many fossil hunters were collecting in western United States; when Yale, Princeton and the American Museum of Natural History were receiving quantities of priceless material, later to be assembled and depicted, in full vitality, by artists who drew and modeled with scientific precision, under the critical eyes of paleontologists.

Most of the drawings of bones and skeletons that illustrated Marsh's publications were made by Frederick Berger, who served as artist at the Peabody Museum from 1875 until well into the 1890's. But perhaps the most talented of Marsh's assistants was Arthur Lakes. Here was an artist who also had field experience collecting bones in Colorado and other regions, as well as laboratory training at Yale, where for a time he helped string fossil remains into articulated skeletons. He was an English clergyman, engaged in the 1870's as teacher in Golden City, Colorado. There he made several notable discoveries of fossils, and not only produced scale drawings of bones as they were excavated, but worked in water color. He was among the first artists to make reliable restorations of prehistoric reptiles as they appeared in life.

It was Edward D. Cope, however, who was one of the first to study the bones of the dinosaurs that were unearthed in the West. His excavations in the marl pits of New Jersey in 1866 had attracted scientific attention. He had brought to

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GIANT GROUND SLOTH AND EARLY ARMADILLOS

IN "BEFORE THE DAWN OF HISTORY," KNIGHT DESCRIBED THE HUGE BUT HARMLESS MEGATHERIUM AS LIVING UNTIL COMPARATIVELY RECENT TIMES ON THE PLAINS OF SOUTH AMERICA. COMPARE THESE MURAL FIGURES WITH SKELETON SHOWN ON PAGE 130.

light remains of carnivorous dinosaurs, including the leaping monster, *Laelaps aquilunguis*. In 1873 he had made restorations of the Eobasileus, or Dawn Emperor of Wyoming, and three years later dug from Montana rock and soil the fossil skeleton of a giant flat-tailed Plesiosaur, *Elasmosaurus platyurus,* with its snaky neck. This reptile Knight depicted years later, hearing from Cope himself a description of the animal and an account of its submarine habits.

Cope's own restorations, in his sketches, now seem crude, but in the 1870's they were unique. Here was a great authority on prehistoric life, toiling day after day to assemble the bones of a dinosaur; then, after months of taxing labor, putting down his conception of the creature as it probably was in life. It was in a letter of January, 1873, that he made one of his first sketches of the Wyoming "Dawn Emperor," then classified as a probiscidean. He marked the sketch, "The horns and head are rather too large. . . ." Another important restoration, done about 1878, was Cope's drawing on brown wrapping paper of an amphibious lizard, the inscription giving its length as 75 feet—the *Camarasaurus supremus* (Cope). Later restorations corrected the shortness of the legs.

Not till 1897, however, did Cope meet Knight, and soon after was assured that this skilled artist could translate into terrifyingly real forms the conceptions developed in decades of scientific study. To his wife in March, 1897, Cope wrote:

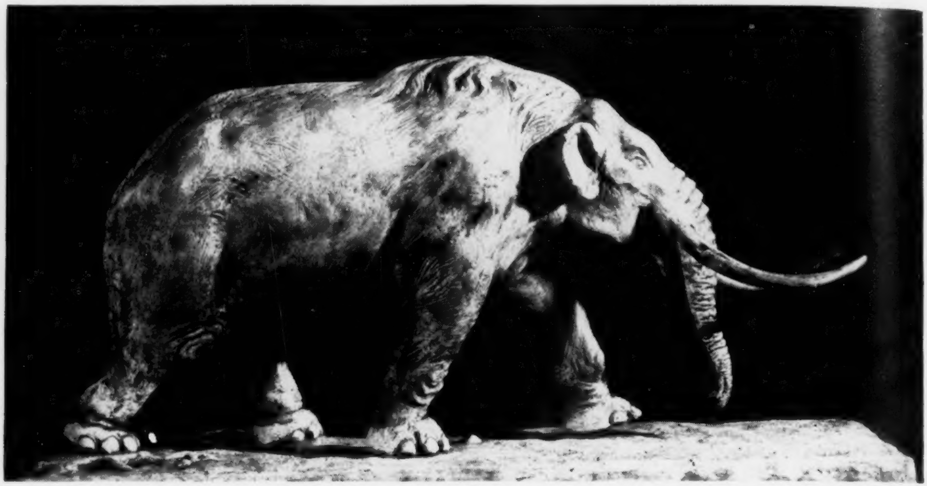
> Professor Osborn was here yesterday and spent a good deal of the afternoon, and we had a pleasant talk. He is going to call on the New York surgeon who attends my case and learn what he can. Mr. Knight, the artist for the Century Magazine, has been here a couple of days, and is getting figures of Naosaurus, Laelaps, Elasmosaurus, Agathaumus, Camarasaurus, and other saurians. He is very original in attitudes.[7]

Three weeks later Cope died. Marsh lived but two years longer. Leidy had passed on in 1891. But the work of all three had laid a vast foundation for the art that was to make fossils live.

Osborn, in his "Impressions of Great Naturalists," made an enlightening reference to Cope's labors, which preceded by many years some of Knight's restorations:

> As a pioneer in exploration among these giant animals he was obliged to draw his conclusions largely from fragmentary and imperfect materials, leaving the field open to Professor Marsh's more exhaustive explorations, which were supported by the government. Yet Professor Cope illuminated the incomplete fragments with his reasoning and his fertile imagination. When a

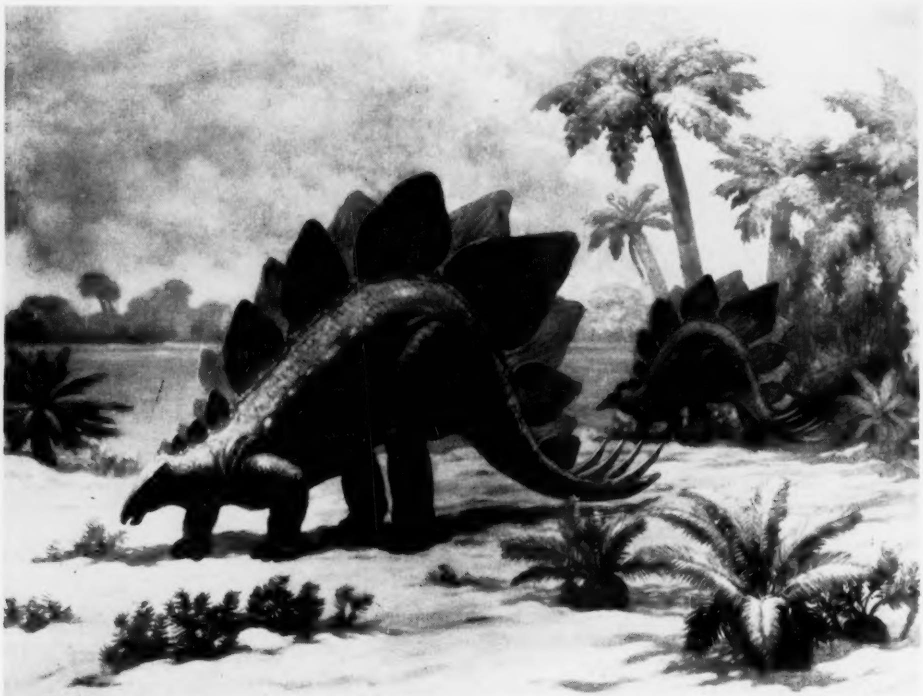
[7] "Cope: Master Naturalist," by Henry Fairfield Osborn, Princeton University Press.



American Museum of Natural History

AMERICAN MASTODON SCULPTURED BY KNIGHT

FORTY YEARS AGO THE AMERICAN MUSEUM OF NATURAL HISTORY, UNDER OSBORN'S DIRECTION, SOLD CASTS AND MODELS MADE FROM RESTORATIONS IN WAX OF FOSSIL VERTEBRATES, SEVERAL OF WHICH COPE HAD DESCRIBED TO KNIGHT.



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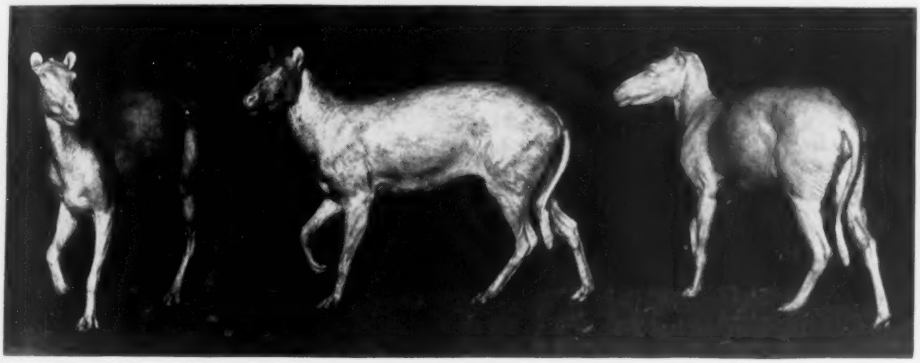
ARMORED JURASSIC MONSTER

THIS RESTORATION OF THE DINOSAUR STEGOSAURUS, WHICH IS IN A MURAL DONE FOR THE FIELD MUSEUM OF NATURAL HISTORY BY CHARLES R. KNIGHT, IS ONE OF A SERIES OF TWENTY-EIGHT LARGE PAINTINGS WHICH REQUIRED FIVE YEARS FOR COMPLETION.

bone came into his hands, his first step was to turn it over and over, to comprehend its form thoroughly, and to compare it with its nearest ally, then to throw out a conjecture as to its uses and its relation to the life economy of the animal. . . . His conclusions as to the habits and modes of locomotion of these animals, often so grotesque as to excite laughter, were suggestive revivals from the vast deeps of time of the muscular and nervous life which once impelled the mighty bones. It is fortunate that some of this imaginative history has been written down by Mr. Ballou and that, although physically enfeebled by a mortal illness, Professor Cope in his last days was able to convey to Mr. Knight, the artist, his impressions of how these ancient saurians lived and moved.

Years elapsed, as we know, between the excavation of fossil bones and the restorations in realistic form by painters and sculptors working from skeletons. Yet it was this, finally, which helped to arouse wide public interest in prehistoric animals. How, to that end, the American Museum of Natural History created more dramatic exhibits is a story too long to tell here. Some of it may be briefly indicated, as the employment of artists was part of an organized effort to inform the public of advances in natural history. Thrust upon art suddenly were greater opportunities than were ever before possible to interpret the science of paleontology for the lay public.

Early in the 1890's Dr. Osborn had begun to set up in the museum exhibits of fossil animals in life-like poses. While in New York in 1896 Professor Schuchert of Yale saw the skeleton of a brontothere mounted by Adam Hermann in accordance with Osborn's ideas. When the method was proposed to G. Browne Goode, then director of the National Museum in Washington, however, Schuchert was informed, in somewhat contemptuous tones, that he had not seen fine paleontology in New York, but fine art.[8] In Washington, as in many other museums, the collections of skeletons of fossil vertebrates were left on the shelves for the exclusive sight of paleontologists—until the movement promoted by Osborn spread.



SCULPTURES OF THE FOUR-TOED HORSE

THESE GRACEFUL MODELS OF EOHIPPUS, A LOWER EOCENE CREATURE ONLY A FOOT HIGH AT THE SHOULDER, WERE MADE BY CHARLES R. KNIGHT FOR THE AMERICAN MUSEUM OF NATURAL HISTORY.

Many technical books, as well as works of popular science published in the early 1900's, however, were more excitingly illustrated than any that had been published in the previous two decades. When Cope's "Batrachia and Reptilia (Extinct) of North America" was published in 1869, it was illustrated almost entirely with drawings of bones, the main plates being done by Edwin Sheppard. This was not a book for the public, it was true; yet even serious students of

[8] "O C. Marsh: Pioneer in Paleontology," by Schuchert and Le Vene, Yale University Press.

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PROCESSION OF WOOLLY MAMMOTHS

KNIGHT PAINTED PICTURES AND MADE MODELS OF LIVING ELEPHANTS AS WELL AS STUDIES OF PREHISTORIC SKELETONS, AND EXAMINED LE MOUSTIER CAVE DRAWINGS AT LES EYZIES, FRANCE, DONE BY CRO-MAGNON ARTISTS.

science could welcome such a work as Frederick A. Lucas's "Animals before Man in North America—Their Lives and Times," published in 1902 by Appleton. The frontpiece reproduced a painting of the Great Horned Dinosaur by Knight, and there were realistic drawings of giant crustaceans, titanotheres and mas-

GIANT WOLVES AND SABER-TOOTHED TIGER

FIGHTING OVER THE CARCASS OF A MAMMOTH IN A PLEISTOCENE TAR POOL IN SOUTHERN CALIFORNIA: A RESTORATION ON CANVAS BY ROBERT BRUCE HORSFALL. ("LAND MAMMALS IN THE WESTERN HEMISPHERE" BY WILLIAM BERRYMAN SCOTT. MACMILLAN COMPANY.)

todons by Gleeson, Knight and others. These restorations were in addition, of course, to photographs and diagrams of skeletons and parts of the creatures discussed. Osborn's "The Age of Mammals in Europe, Asia and North America," issued in 1910, included a preface in which the author explained:

The reader who finds it difficult to picture the rare and ancient forms of mammals has to thank that gifted artist of the life of the extinct world, Mr. Charles R. Knight, for the series of restorations drawn under my personal direction, which are brought together for the first time in this volume. It is always to be understood that such restorations represent hypotheses merely, or approximations to the truth.

This volume was also illustrated by several fine drawings by Erwin S. Christman, of whom we shall tell later.

It was in 1891 that Osborn opened his department of mammalian paleontology at the American Museum of Natural History. His relations with Cope and Marsh had begun as early as 1877, during Osborn's student days at Princeton, when he and William Berryman Scott went fossil hunting in Colorado. For fifteen years, in field work, teaching and laboratory research, he had been accumulating experience for the opportunity that enabled him to present dramatically the story of what science had learned of the great ancient reptiles, and of the forebears of the horse, the rhinoceros and the elephant. His influence on the educational policies of natural history museums in this country is still to be excelled.

COMBAT OVER MERYCOIDODON

HORSFALL HERE DEPICTS "FALSE" SABER-TOOTH TIGER, OR NIMRAVIS, AND TRUE SABER-TOOTH, OR EUSMILUS. PAINTED FOR SCOTT'S "LAND MAMMALS IN THE WESTERN HEMISPHERE."

Before Cope died the American Museum bought his collection. Osborn sent William Diller Matthew to Philadelphia in 1895 to catalogue and pack the mass of fossil material. In the next few years Matthew was able to exercise "a keen interest in the problems that were constantly being raised in the attempts to

mount fossil skeletons in lifelike poses."[9] These problems "were to be solved only by carefully correlated studies on the postures and skeletons of living animals." The work went forward for a while under Osborn's brilliant first assistant, Dr. Jacob L. Wortman. These restorations of the bones of extinct animals provided the sculptors and painters at the museum with abundant material for models and pictures that were vividly realistic, as well as accurate. In turn, the artists helped the museum to design better exhibits.

Before this art was fully developed there were certain important ventures in illustrated journalism, to arouse interest and inform the public with authoritative accounts of what was recently discovered about the reptiles and mammals of the earth's remote past. The achievements of paleontologists in this country had at last become ripe for popular consumption. What Marsh had said in 1875 was no longer true: It was now possible to present good restorations of most of the important extinct animals of the United States.

Marsh himself was long opposed to mounting fossil specimens from his collection for public display. At the end of 1895 he published on a large sheet a dozen illustrations of skeletons of dinosaurs, but this was by no means a gesture toward popular science. Some of the monthly magazines took up the subject, devoting many pages to lively articles, and to illustrations that then seemed sensational, but that were scientifically made. In a few years there was an amazing increase in popular interest in prehistoric creatures.

In the *Century Magazine* for September, 1896, was an article by Osborn

[9] William K. Gregory in *Natural History*, November–December, 1930.

American Museum of Natural History

THE OLIGOCENE BRONTOPS AND EOTITANOPS

LIFE-SIZE HEADS OF TITANOTHERES WERE INSTALLED IN THE AMERICAN MUSEUM OF NATURAL HISTORY IN 1912, MANY MODELS OF WHICH WERE PREPARED BY PROFESSOR WILLIAM K. GREGORY AND ERWIN S. CHRISTMAN. THE LATTER, A GIFTED YOUNG ARTIST, WORKED FOR TWENTY YEARS ON THE RESTORATIONS FOR THE MUSEUM.

entitled "Prehistoric Quadrupeds of the Rockies." The author described the ancient animals in detail. Effectively he dramatized the life and habits of the great four-toed Uintathere of the Bridger region of southern Wyoming and Utah; the Mesonyx, largest of the carnivores; the four-toed horse of Wasatch Lake in the Big Horn Mountains of Wyoming; the Titanotheres of the South Dakota Lake Basin; the Metamynodon, or aquatic rhino, and other creatures until then unheard of by most readers of the *Century*.

In this article it was made clear that every one of the animals illustrated had been restored in skeleton form after many years of hard work, both in the field and in the workshops of Yale, Princeton and the American Museum of Natural History. Osborn included a lively description of fossil hunting. The article was illustrated with reproductions of nine paintings by Charles R. Knight.

Soon after Cope died in 1897 the *Century* carried another article by Osborn on the great naturalist, with illustrations by Knight of leaping dinosaurs and fin-backed lizards. In the same issue was William Hosea Ballou's article, "Strange Creatures of the Past," also illustrated by Knight with six paintings. Here was described Cope's method of examining the skeletons of saurians of the Triassic, Jurassic and Cretaceous eras, Ballou explaining: "During several months preceding his [Cope's] death his original and interesting views upon these animals, and his ingenious speculations regarding their habits, were imparted to the writer." Another of Ballou's articles appeared in the June, 1898, *Popular Science Monthly*. Entitled "The Serpentlike Sea Saurians," it was illustrated with a full-page drawing by J. Carter Beard, as well as with pen drawings by Cope, Marsh and Williston. The Beard illustration was

American Museum of Natural History

PARASAUROLOPHUS WALKERI

A MODEL BY LOUISE GERMANN MADE IN 1937 FROM STUDIES OF A TYPE SKELETON IN THE UNIVERSITY OF TORONTO.

crude and unrealistic in showing "the Great Cretaceous Ocean" filled with very animated Mosasaurs, marine turtles, bulldog fish and a Plesiosaur, from restorations by Williston and Case. Ballou wrote sensationally of the Mososaurs, in a style later used for Sunday supplement articles that may have caused nightmares among readers of Mr. Hearst's New York *American*.

When the Hall of Natural History was formally opened at Trinity College in Hartford, Conn., at the end of 1900, Dr. Osborn delivered there a popular lecture on the recent progress of vertebrate paleontology in America. He declared, "The true modern spirit in which to study a fossil vertebrate is to imagine it as living, moving, walking, swimming or flying, begetting its kind. . . ." He went on to say that it was possible to study a fossil as "thinking,"—as fearing its enemies and devising means of escape—for the organs of sight and smell had been studied as part of "fossil psychology." He explained that one of the great advances of recent work consisted "in the fact that we have secured com-

plete skeletons in the place of fragmentary parts."[10]

That statement of forty years ago, with its emphasis on the psychology of animals, may serve to reveal to present-day readers one secret of the effectiveness of the art then first employed to interpret paleontology to the people. This art was believable as well as exciting, for fossil material had been amassed in quantities. Besides, scientists made new restorations whenever new knowledge radically modified their first conceptions. It was in this spirit that the American Museum of Natural History, from the time of Osborn's efforts to attract public attention to the discoveries of paleontologists, employed Knight, Horsfall, Christman and several other artists.

Knight began by sketching live animals as a hobby. He studied animal anatomy in the taxidermist shop of the museum while he was working as a designer for J. and R. Lamb of New York, makers of stained glass. He was born in Brooklyn in 1874, attended Brooklyn Polytechnic Institute, and studied at the Art Students League. In his book, "Before the Dawn of History,"[11] he mentions the incident that opened for him the career he has followed for forty-eight years. One day in 1894 Dr. Jacob Wortman of the American Museum asked Knight to make a small water color of the Elotherium. From various complete skeletons and skulls the artist made a restoration that was satisfactory. He believes that his principal equipment for such work from the beginning was his "intense love of and interest in the forms and attitudes of living animals." He has frequently said that no artist can put life into drawings and paintings of extinct animals unless he knows something of the life, attitudes and psychology of living creatures.

Working under the supervision of Osborn, Wortman, Matthew and others at the museum, Knight helped devise a

[10] *Science*, January 11, 1901.

[11] Whittlesey House, 1935.

MODEL OF BRONTOSAURUS—A JURASSIC DINOSAUR

CONSTRUCTED BY JAMES E. ALLEN AT THE AMERICAN MUSEUM OF NATURAL HISTORY.

SKELETON OF EMEUS CRASSUS
IN THE COLLECTION OF FIELD MUSEUM OF NATURAL HISTORY.

EMEUS CRASSUS RESTORATION
THE SKELETON AT THE LEFT PROVIDED THE BASIC FORM FOR THE PAINTING BY J. C. HANSEN.

method of making pictorial reconstructions from the inside out. In three or four years his application to this work produced remarkable results. He had illustrated books and magazine stories in the early 1890's, but from the time he began drawing and painting for paleontology he developed an acute sense of the vitality of the ancient creatures he depicted. It was his primary purpose to impart life to his restorations, so that fossil mammals and reptiles would become almost as familiar as modern horses and dogs to all who saw his models or pictures.

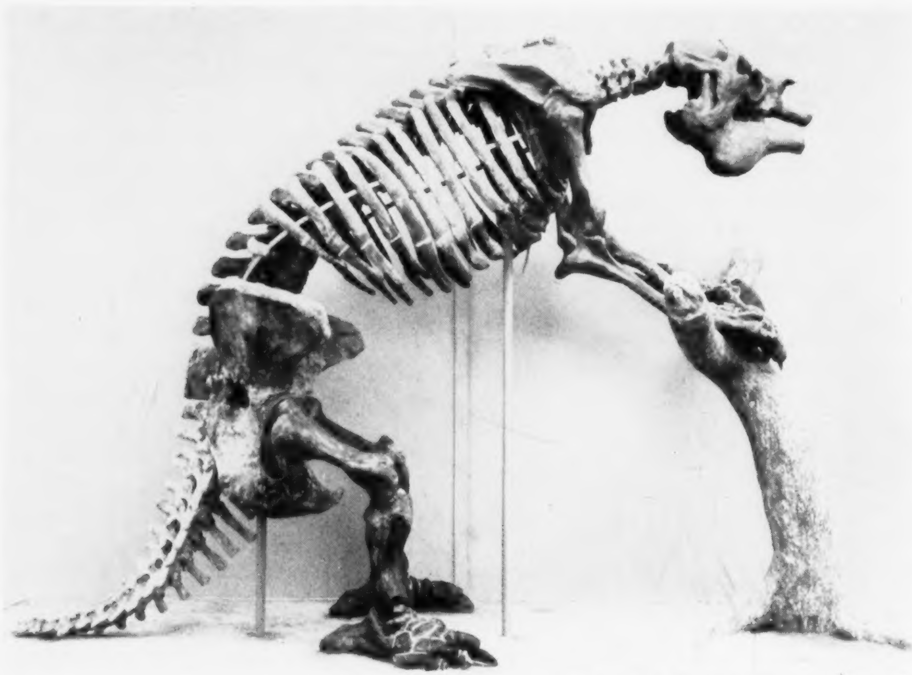
In the spring of 1898 the museum issued a catalogue of casts, models and photographs of restorations of fossil vertebrates. Reviewing this in *Science*, Osborn referred to "the difficulty of arousing interest and spreading accurate information among a very large class of inquisitive but wholly uninformed people." To overcome this difficulty members of the Department of Vertebrate Paleontology of the museum had made special studies of methods of holding the interest of visitors to the museum. One result was the exhibition with fossils of the series of water colors by Knight. Several of the creatures illustrated in the catalogue of casts were those whose movements were described to Knight by Cope. Among these was, of course, the leaping dinosaur. Knight's model was based on the fragmentary skeleton in the Cope collection, and on restorations by Marsh of the allied form, Ceratosaurus.

It was the artist's practice to make first a number of models in wax in accordance with the proportions and muscular indications of the skeleton. From evidence at hand he was able to draw conclusions about the feeding habits of the animal, and its attitudes, as shown by the positions of the joints and the angles of feet and limbs. Then, to get the solidity of three dimensions on paper, and to reproduce shadows of the animals on the ground, the models were placed in sunlight, and the paintings made from them. It was when Osborn decided the wax models themselves were worth preserving that casts were made and a catalogue issued. Colleges, scien-

tific schools and individual students could thus obtain material for study. The original sculptures and paintings were a gift to the museum from J. Pierpont Morgan.

By early summer of 1898 Knight had made about twenty water colors and a number of models, and had begun others. The artist's realistic poses of ancient animals had considerable influence on the designing of displays for the museum. Skeletons of many specimens were mounted after his models. The artist made a notable series of models of primitive elephants, and in the early years of this century a series of restorations of Pleistocene and Miocene horses. Probably Knight has become most widely known for his murals in the American Museum of Natural History, and in the Field Museum in Chicago. His first large wall decoration was begun in the New York museum in the Hall of the Age of Man. For the next ten years he was engaged in painting the series of wall panels which have impressed all who have sought in pictures a clearer idea of life on earth as it must have appeared in the main phases of its evolution. Knight then did twenty-eight large panels for the Field Museum, between 1926 and 1930, and returned to decorate the Hall of the Age of Mammals in the American Museum.

One of the latter panels shows mammals of the Upper Pliocene period: the short-jawed Stegomastodon, the Glyptotherium, an armadillo-like animal, and the one-toed horse Plesippus, also the early camel, or Pliauchenia. Another panel, completed in 1934, when Knight observed the fortieth anniversary of his



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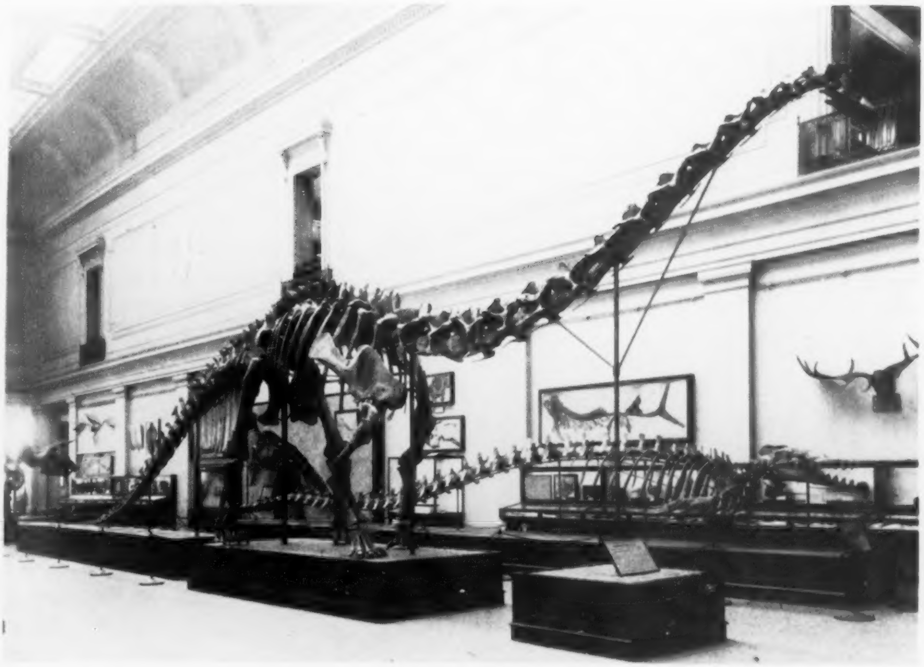
THE SKELETON OF A GIANT SLOTH

A GOOD SPECIMEN OF MEGATHERIUM WHICH DISCLOSES SOME OF THE EVIDENCE ON WHICH KNIGHT MADE HIS ANATOMICAL STUDIES FOR THE MURAL SHOWN ON PAGE 121.



SKELETON OF A DINOSAUR, SEVENTY-TWO FEET IN LENGTH
THIS RESTORATION OF DIPLODOCUS LONGUS MARSH IN THE UNITED STATES NATIONAL MUSEUM WAS SHIPPED PIECEMEAL TO THE CAPITOL FROM THE DINOSAUR NATIONAL MONUMENT IN UTAH.

association with the museum, illustrates mammals of the Oligocene period in a restoration of a typical scene in Nebraska and South Dakota. In the Museum of Natural History in Los Angeles is a fifty-foot panel of the Rancho-La-Brea pitch pools. The mural in the Planetarium in New York, by the way, is also by Knight; it illustrates the story of the Moon Goddess in the mythology of the Plains Indian. In 1940 Knight made his first lithographs, a series of fourteen, illustrating invertebrate and vertebrate creatures through the ages. His paintings have been reproduced in countless books and magazine articles on prehistoric life.

Another talented artist who came to the American Museum of Natural History before 1900 was R. Bruce Horsfall. He recalls that it was Osborn's quest for a pen and ink draughtsman that first brought him commissions in 1898. Horsfall, whose studio is now in Washington, has had a distinguished career as artist, author and naturalist. Born in Iowa in 1869, he studied in Cincinnati Art Academy and in Munich and Paris, and exhibited in the Chicago Exposition of 1893. In addition to his work for the New York museum, which chiefly consisted in drawings of fossil skeletons, he did restorations of extinct animals for *McClure's Magazine*. Professor William Berryman Scott employed him to illustrate the fossils of Patagonia, on which he spent some eight years. He made illustrations for Scott's "A History of Land Mammals in the Western Hemisphere," first published in 1913, and also painted backgrounds for museum displays.

A gifted lad of 15 came to the American Museum of Natural History one day

in 1900. He was encouraged to copy skulls and make other studies of anatomy, and to play about with pencils and modeling clay. This boy had an extraordinary interest in animal life and was able to express that interest in art. His name was Erwin S. Christman, and he spent more than twenty years of his short life as an artist for paleontology. In particular he developed an ability as sculptor, and became a valuable member of the museum's staff before he was much older than the average college freshman. He studied at the Art Students League and the American Academy of Design. He obtained some of his earliest practice in the difficult branch of art he had chosen by making wash drawings of the teeth of Titanotheres.

Then Christman turned to pen and ink, and modeling clay, and made a series of drawings of the skeletons of dinosaurs. One of his notable achievements was the restoration of the dinosaur Camarasaurus. From innumerable drawings of the bones, and after years of painstaking work, he made cut-outs and arranged these in a realistic pose. This he used as the basic design for what has been considered one of the best sculptured models of a dinosaur ever made.[12]

Osborn's "The Age of Mammals in Europe, Asia and North America" included several photographs of Christman's models of primitive Proboscideans and other mammals. In April, 1912, the museum installed an exhibit of a series of life-size heads of the Titanotheres, those gigantic horned monsters that once roamed the plains of the Dakotas and were distant relatives of the rhinoceros. These, displayed in the Hall of Vertebrate Paleontology, were modeled by Christman under the direction of Osborn and Gregory. A few years later Gregory and Christman, after arduous research,

[12] "Erwin S. Christman—Draughtsman, Artist, Sculptor," by William K. Gregory, *Natural History*, November–December, 1921.

United States National Museum

ARMORED DINOSAUR IN THE UNITED STATES NATIONAL MUSEUM

THE LIFE-SIZE RESTORATION OF STEGOSAURUS WAS MADE FOR THE ST. LOUIS EXPOSITION OF 1904. THE MUSEUM HAS A SKELETON SHOWING ARRANGEMENT OF THE DERMAL PLATES.

succeeded in devising a complete restoration of a Titanothere which, for the first time, presented the musculature of those creatures. Christman died in 1921 at the age of thirty-six, after more than twenty-one years' service to science and education. In a fine tribute Dr. Gregory wrote of him that "his work was characterized not only by creative vision but by fidelity of detail," and praised him as an intelligent and sympathetic assistant to the scientific staff.[13]

Among the artists who have worked for the museum in more recent years have been John C. Germann and Louise Waller Germann; E. Rungius Fulda, whose painting of a Miocene camel bed-ground was done under direction of Dr. Barnum Brown; and M. Flinsch, who made a number of drawings of elephants and mastodons. Charles J. Lang made a reconstruction of the Longirostine Mastodont.

The art director of the agency in charge of advertising for Sinclair Oil Company saw in *Collier's Weekly* about ten years ago an illustration of a Jurassic sea monster. He commissioned the artist, James E. Allen, to do a series of dinosaurs for advertising illustrations. Few readers who saw them knew how much careful work went into these. Allen made numerous studies at the American Museum of Natural History under the supervision of Dr. Barnum Brown, with guidance from Dr. Walter Granger, Dr. Robert C. Murphy, Dr. Gregory and others. A handicap under which he worked was, of course, the speed with which commercial illustration is required. His dinosaurs were later reproduced in booklets and on stamps that were printed in some 5,000,000 copies, to supply requests from a public that responded with intense interest to this example of art in the service of science.

[13] *Natural History*, November–December, 1921.

At the Field Museum in Chicago many restorations of fossil vertebrates have been made by John Conrad Hansen. His crayon and pencil drawings and pen and ink studies of prehistoric animals have been used by the museum to illustrate cased exhibits of the articulated skeletons. Born in Trondhjem, Norway, seventy-three years ago, he came to this country as a boy and lived in Minneapolis. There for nearly forty years he worked as a lithographer, specializing in vignette engraving for the Monarch Lithographic Company. He opened a commercial studio in Chicago in 1929, and joined the staff of the Field Museum about four years ago. Since early youth he has painted portraits, landscapes and figure studies in oil.

The art that has interpreted the life work of America's paleontologists, as we have seen, has been more than technical illustration—it has often been fine art. It has required an extraordinary combination of talents, for its best practitioners not only have had the full equipment of professional artists—they have adapted their technique to illustration, which was made dramatic to attract interest. They have approached their subject with more than ordinary understanding of animal anatomy. They have worked, for the most part, with material which required a happy blend of imagination and scientific precision; material on which they must exercise skill and patience under the eyes of scientists who would not approve work in which imagination had run away with fact. These have been the rigid requirements of a branch of art which has, in most instances, brought little recognition to the artist, but which has made a major contribution to education—to the more effective use of museums as educational institutions.

SOIL AND WATER ECONOMY IN THE PUEBLO SOUTHWEST

II. Evaluation of Primitive Methods of Conservation

By Dr. GUY R. STEWART and Dr. MAURICE DONNELLY

SOIL CONSERVATION SERVICE, U. S. DEPARTMENT OF AGRICULTURE

In the work carried out so far, we have found five principal types of conservation practice which were used by the early Pueblo farmers. The first of these consisted of boulder bench terraces which received local run-off from adjacent slopes, and so supplemented the rainfall by adding the precipitation from tracts several times as large as that on which the crop was planted. Many such plots were tiny in size, even 8 by 10 feet in area, but in most cases consisted of a series of two or three boulder checks which would have helped to retain run-off coming onto small gardens 75 to 100 feet long by 20 to 30 feet wide. The large terraced site on the Walhalla Plateau is an example of field scale water conservation upon this type of area, where local run-off was arrested. Very few terraces of this sort were on level land, and even with gradients no steeper than $2\frac{1}{2}$ to 3 per cent. there has been a gradual loss of surface soil. In their simplest form boulder bench terraces merely reduced the velocity of flow of run-off water, thereby increasing the water intake into the soil. It is probable that this type of moisture- and soil-saving dam was first constructed after some early cultivator observed that water was retarded and soil retained by fallen tree trunks which lay across small drainage depressions. Where rocks supported and reinforced the tree branches or trunks it was found that the structure was likely to be more permanent. The natural occurrence of simple wood and rock water-arresting checks has often been observed by us at Mesa Verde and at other points in the Pueblo country, and such demonstrations could not have failed to attract the attention of a primitive cultivator.

The effectiveness of the ancient boulder and rock bench terraces depended on the steepness of the slope on which the structure was placed and on the care with which the boulder or rock wall was constructed. On slopes of 6 to 8 per cent. there was little retention of soil, but on gentle slopes, under 3 to 4 per cent., terraces of this class have effectively held soils of stable structure until the wall was breached by floods.

The use of land receiving local run-off in present-day Pueblo agriculture can be seen in the bean fields adjacent to the Hopi mesas or the corn fields at Nutria on the Zuni reservation, which are supplied with additional water from surrounding hill slopes.

A second group of conservation installations which can still be identified, both in the northern and southern portions of the Pueblo country, were the village check dam plots, placed in the upper part of any convenient watercourse where the grade was not too steep and the stream flow relatively gentle. In most cases, other than at Mesa Verde, these check dam gardens were on a slope of 4 to 6 per cent., so that the resulting plot had a moderate grade of $1\frac{1}{2}$ to 3 per cent. When first installed these plots were probably effective devices to conserve soil and water as the soil was of moderate depth and surplus water filled the root zone after each rainfall which produced run-off. There was, however, some washing away of the sloping surface soil so the greater part of

ANGELS WINDOW, NORTH RIM, GRAND CANYON, NEAR WALHALLA PLATEAU.

these installations could not be classed as a method of stabilizing a permanent system of agriculture. At Mesa Verde, this type of garden plot had the best development which we have discovered so far. A definite type of construction can be recognized, with the ends of the checks carefully tied in to the sides of the stream channel and the dam itself built up to a sufficient height so that a level plot resulted. The portions of these plots which now remain at the sides of the streams indicate that excellent small gardens were formed, with an adequate depth of soil for corn, beans or squash. While the dams were kept in repair the Mesa Verde type of garden check may be classed as a splendid installation well designed to conserve soil and utilize storm run-off for crop production.

A third type of conservation practice was the use of flood water distributing ditches to bring flash stream flow or surface run-off onto corn land or garden patches. This conservation measure had its greatest development in the widespread ditch system of the Salt River Valley, which one of us[1] has discussed previously. These ditches are often described as a system of irrigating ditches. From all the evidence of the general use of impounded flood water for crop production in the Southwest, it appears probable that the Salt River Valley system was a well-organized method of distributing and spreading flood flow.

The Mesa Verde flood water ditch is the only instance we have discovered so far of this method of handling water in the northern Pueblo country. The ditch trapped a large flow of run-off, both from the uplands and from ground immediately adjacent to it. Along the ditch there are remains of small field checks and recognizable areas of probable diversion onto corn land. These accessory methods of slowing up run-off, impounded soil and increased the penetration of water, thereby retaining a greater supply of moisture for plant growth.

BOULDER TERRACES OF SMALL ROCK

UPPER PART OF A LARGE TERRACED SITE ON THE WALHALLA PLATEAU, GRAND CANYON.

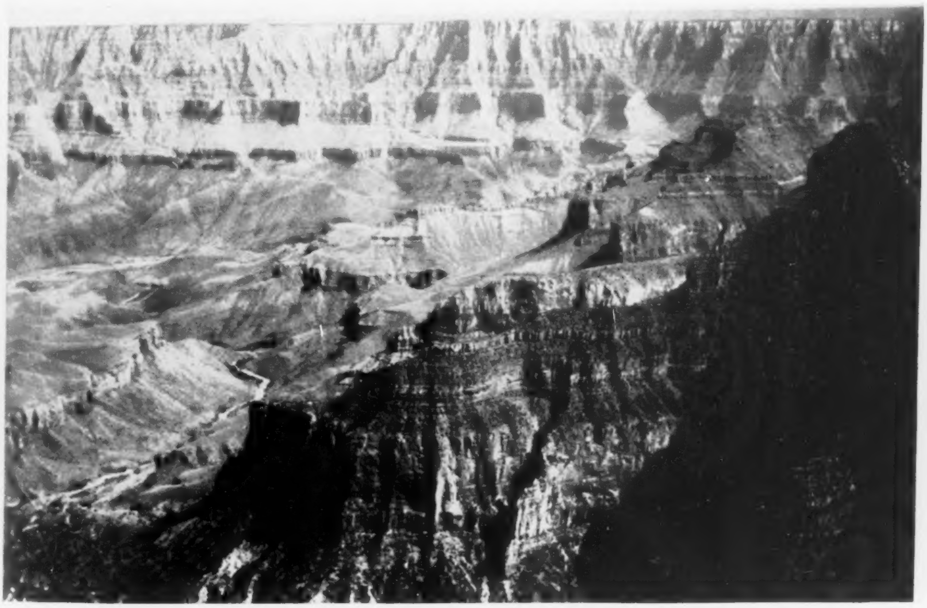
The wide, relatively flat channel of this ditch suggests that it may have been planted to corn in the same manner that natural flood waterways in modern Hopi or Zuni corn fields are still treated.

A fourth method of conservation of water was the use of springs or small, live streams for the irrigation of village garden plots. The Tohalena Gardens, near Navajo Mountain, were an example of a garden area, which was supplied with water, partly by run-off from the hills to the northeast and partly by flow from a live spring. The rainfall and spring flow were conserved by throwing up banks to surround the plots which were frequently built up on step-like terraces. Gardens of this type, which have been cultivated intensively by the Hopis since early days, can be seen at Hotevilla and Wipo Springs, and on a smaller scale wherever continuous flow of water was available adjacent to the Hopi villages.

The fifth and most important practice consisted in cropping the flood water fields where the principal corn crops of the villages were produced. By the use of temporary brush and soil dams, occasionally reinforced with rock, water from flash floods was diverted from its normal channel across adjacent fields where it could be impounded and absorbed into the soil. Strangely enough, even though these tracts were the largest areas of the crop land that was planted, they are often the most difficult primitive sites to recognize at the present day. This is because a relatively small amount of rock was used in the water-spreading dams which deflected the water across the corn land.

A typical flood plain field was almost level with a slight fall of about 1 per cent. so that it was easy to distribute the water over the entire area. Cushing[12] was one of the first to make detailed

[12] Frank H. Cushing, "Zuni Breadstuff," New York Museum of the American Indian, Heye Foundation, 1920.



VIEW OF THE NORTH RIM OF THE GRAND CANYON
NEAR ONE OF THE VILLAGE SITES ON THE WALHALLA PLATEAU.

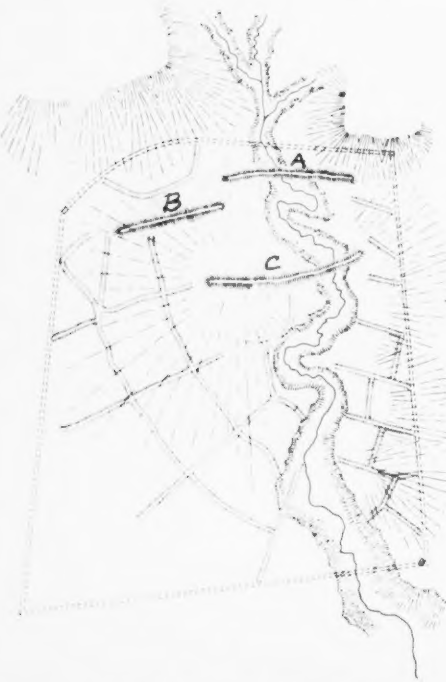


FIG. 4. PLAN OF ZUNI CORNFIELD IN 1884. AFTER CUSHING.

studies of flood water irrigation by Pueblo methods. In his residence at Zuni as a member of the tribe from 1880–85 he interested himself in all the agricultural operations, as well as in the ceremonial life of the tribe. The manner in which a Zuni cultivator handled the flood water flow on a field in 1884 is shown in Fig. 4. A dam of earth and brush was placed across the stream at the top of the field at A. This deflected the water over to the secondary spreader B, and as the water swept round B, the earth dikes were cut through and then closed to retain impounded water. An additional dam at C again kept the water from flowing down the main channel and helped to turn it over the balance of the field. Cushing notes that it was frequently possible to reclaim a sandy flood plain for agricultural use by turning silty flows out over the sandy land for a season or two until the water-holding capacity of the sandy soil had been improved.

Essentially the same process of flood irrigation can be seen on many of the Zuni fields now in use and a careful study was made of the methods followed on all the Zuni corn land during the season of 1940, through the cooperation of Melvin Helander, Zuni agent for the Indian Service. The manner of handling the corn land was discussed with a number of the older Zuni, who were all agreed that the practice of flood irrigation traced back to their ancestors. The principal change which has occurred recently has been the introduction of plowing, which is now causing modifications in the early planting technique described by one of us[1] previously. One of the larger fields examined in 1940 had a series of four dams across the stream channel to spread the flood water over the field. The secondary effect of the dams was to keep the stream bed on the same level as the field and prevent the development of gullies. By this method of treatment the stream channel did not always stay in one place, so the entire field, including the stream, was planted in its entirety. A heavy flood flow might alter the course of the main channel and wash out a strip of corn, but the loss was no greater than if the strip of land along the main stream bed had been left free from a crop. Planting corn in the stream also has aided in reducing the turbulence of the flood flow and was one of the few instances where we have seen the corn plant used as an accessory vegetative aid in the control of small flood flows.

The discussions with Zuni cultivators brought out several of the risks to which flood-water farming is subject. At times an excessive amount of sand may be deposited in, and adjacent to, the stream channel so that a part of the land will not retain water sufficiently to carry the crop through periods of drouth. The

Zuni informants claimed, however, that this condition may be corrected by later flows in the season, but sometimes continues until more silt is deposited in the following year. An exceptionally heavy flood flow occasionally washes out portions of the planted crop, but the philosophic comment was made that the rest of the field would probably yield enough to make up for this loss, because of the extra supply of water received. The only thing which they felt permanently injured a flood-water field was deep trenching or gullying of the stream channel, which would make it impossible to turn water out on the land. Such gullying must be checked by preventive dams as soon as it began. Reagan[13] has indicated his belief in the importance of the filling in of valley flood-water fields in the Pueblo country as a preventive of serious erosion and gullying.

[13] Albert B. Reagan, "Stream Aggradation through Irrigation," *Pan-Am. Geologist*, Vol. 42, No. 5, pp. 335–344, 1924.

The fact that the evidences of the early use of land for flood-water fields is now often difficult to detect makes us urge that archeologists working in the Southwest devote more attention to reporting such information. Certainly a solution of the manner in which the primitive peoples of the Pueblo country lived and adapted themselves to their environment should be of interest to all scientists working in this portion of the country, and warrants a united attack by both agriculturists and archeologists. In the case of some sites, as of Chaco Canyon, the very location of the corn fields which would have supported the large communities residing there has been a matter of question. Several reports quoted by Hodge[14] have suggested that one or more primitive ditches were used to take water from the canyon and irrigate fields at

[14] F. W. Hodge, "Handbook of the American Indians North of Mexico." *Bull.* 30, Bureau Amer. Ethnology, Parts 1 and 2, Washington, 1907–1910. Section on Irrigation, p. 620.

STREAM CHECK DAM, BELOW RAINBOW LODGE, NAVAJO MOUNTAIN.

PRIMITIVE BOULDER FIELD CHECK AT TOHALENA GARDENS
ABOUT TWO MILES FROM NAVAJO MOUNTAIN.

some distance from the main villages. There has been some difference of opinion, however, whether these ditches described may not have been constructed by the Navajo during the early period of their residence in the country.

Through the cooperation of the Soil Conservation Service Office at Albuquerque, an examination of the entire area adjacent to Chaco Canyon was made from the air. No signs of a large system of diversion ditches, which would have watered corn land sufficient for the Chaco villages, could be detected. On the other hand, the aerial study of Chaco Canyon and the adjacent Escabada Wash suggested that these two streams had adequate areas of land suitable for flood-water corn fields in the canyon beds, themselves. The main gully running down Chaco Canyon has every appearance of being a channel cut in recent years. Were this channel not present, the stream flow could be spread in many places to form an excellent system of corn fields. When Simpson[15] passed through Chaco Canyon in 1849 he described conditions there in some detail and stated that the stream near his camp not far from Pueblo Wejiji had a width of 8 feet and a depth of $1\frac{1}{2}$ feet and that occasional patches of excellent grama grass were located along the canyon. There was no mention of the deeply trenched gully that the stream now occupies, which apparently had not been cut out at the time of Simpson's visit.

The country surrounding Chaco Canyon is as heavily grazed as the areas we have examined adjacent to Navajo Mountain. It, therefore, seems probable that the rapidity of run-off has increased in modern times with consequent trench-

[15] James H. Simpson, "Report of an Expedition into the Navajo Country in 1849." In reports of the Secretary of War, Senate Ex. Doc. No. 64, 31st Cong., 1st Sess.

ZUNI CORN FIELD AND FARMSTEAD AT NUTRIA
CORN LAND RECEIVES RUN-OFF FROM ADJACENT HILLS.

ing of fields which could originally have been used as flood-water corn land. Even had there been no increase in the rate of run-off, the observations made at Zuni show that catastrophic gullying of corn land can occur in flood-water fields when diversion dams no longer stabilize the channel. Hence, disuse alone might have started the formation of a deep arroyo. It appears probable that reduction in vegetative cover after the time of Simpson's visit has intensified run-off and contributed to the destructive process.

All the ancient conservation installations that we have examined have undergone moderate to severe soil erosion. The period when this erosion took place is difficult to determine at the present day. If soil washing was occurring during the time of early settlement it might account for part of the shift in the prehistoric population. The Pueblo people had no livestock to reduce vegetative cover over a wide extent of surrounding country. They did have an appreciable need for firewood and timber for support of the upper floors of the houses. It is difficult to estimate whether wood and brush cutting would have been so complete that erosion might have been accelerated on the sloping village fields. Our examination of one large terraced site on the North Rim of the Grand Canyon indicated that erosion might have occurred at an early date. This is not the case for the region as a whole.

There is, in fact, considerable evidence that vegetative cover on at least part of the Pueblo country has decreased within historic times with a consequent increase in the susceptibility of appreciable areas to sheet erosion. This is shown in a series of reports of official expeditions made across portions of the Pueblo country in the period of 1846–1857. Lieu-

tenant Colonel Emory[16] accompanied the first United States military expedition into New Mexico in 1846. After the occupation of Sante Fe, Emory was a member of the army which proceeded down the lower Rio Grande, and then turned across the mountains until the Gila was reached and followed to the Colorado. At a number of places in his journal he described the typical vegetation on the lower Rio Grande, which included large patches of grama grass. Later, while crossing the table land enroute to the Gila, he commented on the great abundance of the winter grama grass. Occasional notes were made by Simpson[17] of the supply of grass for teams and stock in his report of the survey of the wagon route from Fort Smith, Arkansas, to Santa Fe, New Mexico, in 1849. Sitgreaves[18] made a journey from Zuni to the Colorado River in 1852, crossing the country below the San Francisco Mountains. In his report he mentioned the excellent grass cover found on the hills away from the stream. Whipple,[19] on his railway survey near the 35th parallel of latitude, crossed the Pueblo country in 1853 approximately along the route of the present Sante Fe Railroad and commented on the thick carpet of grama grass that covered the western hills.

[16] Lt. Col. W. H. Emory, "Notes of a Military Reconnaissance from Fort Leavenworth in Missouri to San Diego, California." (Made in 1846–7 with the advanced guard of the Army of the West). Thirtieth Cong., First Sess., Ex. Doc. No. 41, Feb. 9, 1848, pp. 1–614.

[17] James H. Simpson, U. S. Engineer Dept. Report from the Secretary of War Communicating the report and map of the route from Fort Smith, Arkansas to Santa Fe, N. M., Washington, 1850. U. S. 31st Cong., 1st Sess., Senate Ex. doc. No. 12, 25 pages, 4 maps.

[18] L. Sitgreaves, Report on an Expedition down the Zuni and Colorado Rivers, Senate, 32nd Cong., 2nd Sess., Ex. Doc. No. 59, pp. 1–190, with plates, Washington, 1853.

[19] Lt. A. W. Whipple, "Report of Explorations for a Railway Route near the Thirty-fifth Parallel of Latitude from the Mississippi River to the Pacific Ocean." 33rd Cong., 1st Sess., Ex. Doc. No. 129, pp. 1–154, 1854.

The most detailed report of vegetative growth, however, is that made by Beale[20] covering his survey of the wagon road from Fort Defiance to the Colorado River in 1857. As this route was intended for the use of emigrants to California he made detailed notes on the supply of grass and water for stock and wood for cooking. He summarized his observations as follows: "You will find by my journal that we encamped sometimes without wood and sometimes without water, but never without abundant grass." Recently Lockett[21] has followed the Beale Trail through the Navajo country and has shown photographically the great change which has occurred in loss of vegetative cover and resulting soil erosion at Beale's camp sites, except at a few locations where grazing has been controlled.

Probably the most eroded sites examined by us were those located on the slopes of Navajo Mountain, where the grazing by sheep in late years has been heavy. In addition, the soils at the mountain foot are largely sandy or gravelly in texture, showing poor resistance to erosion.

The land at Mesa Verde was grazed only moderately by cattle prior to 1906, and is now protected by better vegetative cover than is found around Navajo Mountain. The soils on most portions of Mesa Verde visited by us are loams or silt loams, which appear to be less erodible than the looser soils of the Navajo Mountain area so that a good portion of the surface horizons are still in place on the mesa.

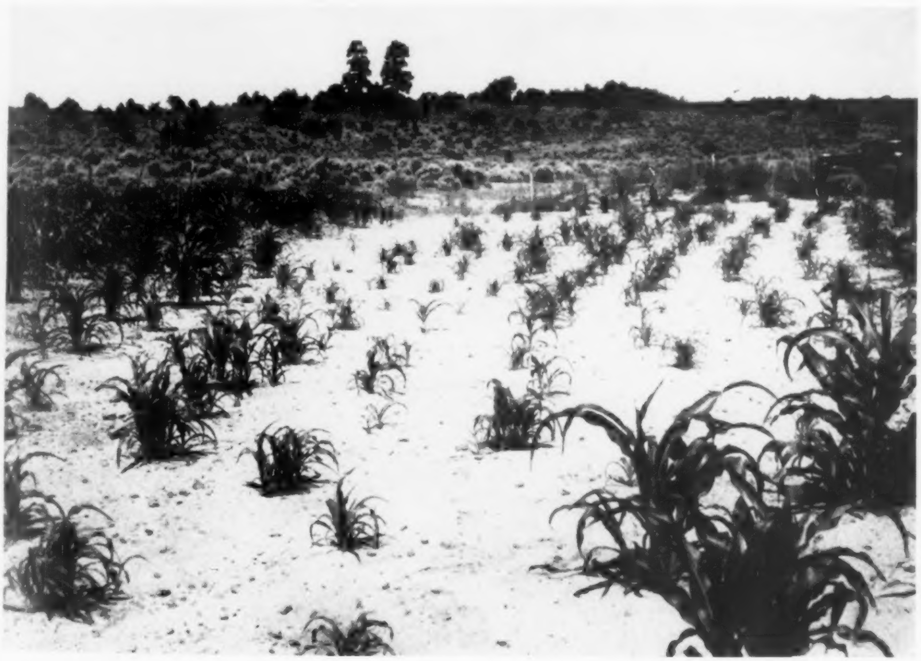
In a careful review, Bryan[22] examined the records of early travelers and explorers in the Southwest in an endeavor

[20] E. F. Beale, "Wagon Road from Fort Defiance to the Colorado River." House of Representatives. Executive Doc. No. 124, 35th Cong., 1st Sess., Washington, 1858, pp. 1–87.

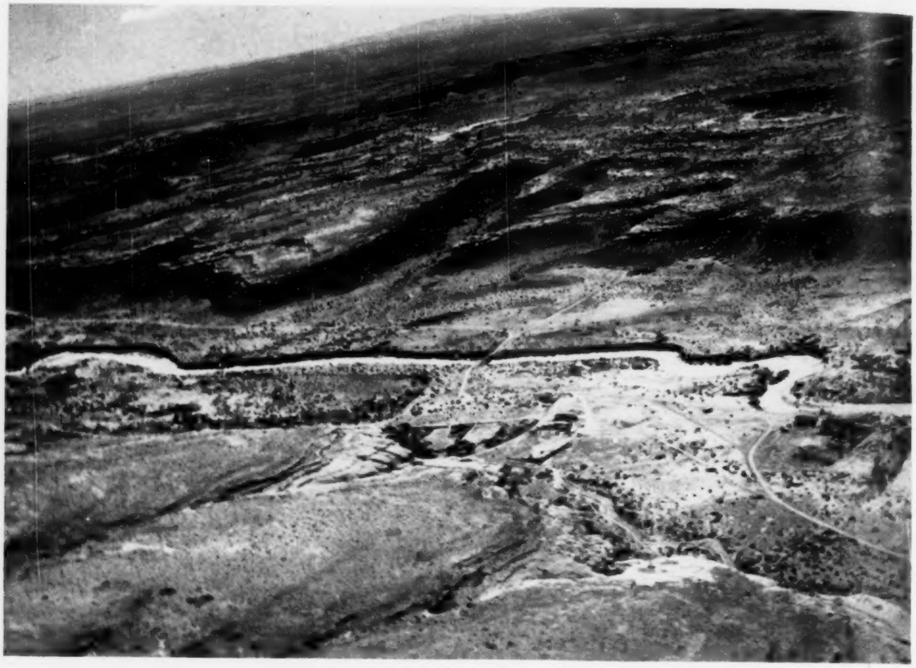
[21] H. C. Lockett, "Along the Beale Trail," Education Div., Office Indian Affairs, U. S. Dept. of Interior, 1939, pp. 1–56.

[22] Kirk Bryan, *Science*, 62: 338–344, 1925.

RUINS OF HAWIKUH, SOUTH OF ZUNI
THIS IS THE SITE WHERE CORONADO FIRST MET THE PUEBLO PEOPLE.



TYPICAL FLOOD WATER FIELD ON THE ZUNI RESERVATION
THE PLANTED STREAM CHANNEL IS IN THE IMMEDIATE FOREGROUND.



VIEW OF PUEBLO BONITO AND CHACO CANYON FROM THE AIR
SHOWING THE DEEP STREAM GULLY WHICH HAS APPARENTLY DEVELOPED IN HISTORIC TIMES.

to date the cutting of arroyos in the Southwest. He concluded that active cutting of most of these arroyos (channels) was initiated within the last one hundred years. The present period of arroyo cutting in the semi-arid Southwest coincides, then, with the period of decline in the density of vegetation. Along with other evidence, Bryan's conclusion gives support to our belief that a considerable part of the sheet erosion on ancient agricultural sites, now abandoned, has taken place in comparatively recent time.

Conclusions

(1) The conservation practices examined at four early centers of Pueblo culture had excellent value as water conserving devices. Essentially the same methods have carried over into present day Pueblo agriculture and are in successful use.

(2) Boulder bench terraces on sloping land, probably never gave effective control of soil erosion, but may have had some value on areas where vegetative cover was sufficient to reduce the velocity of run-off water. Check dam bench terraces built so that a level plot of soil was formed, were excellent soil conserving structures so long as they were repaired and maintained. The flood water irrigation fields, on which the major portion of the early corn crops were raised, had an important place in conserving soil and when handled by the Pueblo methods of water diversion, effectually prevented gullying.

(3) The primitive conservation practices of the early Pueblo farmers demanded constant vigilance to maintain them in use and showed that the agricultural economy of this region was delicately adjusted to the needs of the early communities.

SIRENS AND BELS

By Dr. J. O. PERRINE

ASSISTANT VICE PRESIDENT, AMERICAN TELEPHONE AND TELEGRAPH COMPANY

THE present war is a technical war. Never before have the scientist and the expert been called upon in such large numbers to apply their wide array of techniques to the purpose of war. However many new phases there are in this war compared to previous wars, one outstanding difference is the airplane. As a result of the airplane and bombings and air attacks on military and civilian areas, the production of a shrieking, howling and roaring siren signal became another problem that could be attacked and solved with technical knowledge.

ACOUSTIC ENVIRONMENT

In days gone by our environment was largely visual. Since the last war we have been living in a new environment, an acoustic environment. From radio loud speakers and public address systems in home, theater, stadium and school, words and music are pelted at us. We have all become sound-conscious as never before.

To be sure, sound is a commonplace phenomenon and likewise a simple phenomenon. However, from the engineering point of view sound seemed to have defied measurement technique. Engineers, of course, seek to measure, to calibrate, to quantitatively evaluate. But sound waves, intangible and invisible and fragile and impotent as stuff for an engineer to work with, did not readily submit to quantitative analysis. Even electricity lent itself to measurement more readily than did sound.

FIG. 1. ELECTRICAL METER FOR MEASURING INTENSITY OF SOUND

MEASUREMENTS ARE CALIBRATED IN DECIBELS. A MICROPHONE IS CONNECTED EXTERNALLY.

(Courtesy of PM)

FIG. 2. THE CHRYSLER–BELL VICTORY SIREN

WHICH PRODUCES THE LOUDEST CONTINUOUS NOISE EVER CREATED BY MECHANICAL MEANS.

Sound and Electricity

Happily, during the last quarter century sound has submitted to engineering technique via the development of electrical communication. Sound became measurable when translated to electrical currents. These fine techniques, contributing of course in times of peace in splendid fashion to the interrelations of speech, music, radio and telephony, were very promptly applied to the problem of making a sound, just sound—noise, if you will—a very loud sound. This is where the siren comes in. In an airplane attack, the pantosonic roar of a siren became the best means of warning the countryside. Sound is the Paul Revere of 1942. It travels swiftly, 770 miles per hour, and can now be made loud enough to be heard adequately at a distance comparable to that from Old North Church to "the rude bridge that arched the flood" at Concord.

Sound Is Power

It has already been suggested that, in engineering circles, sound was an obstreperous sort of phenomenon. To measure the frequency of vibration of sounds was not difficult, but to measure the sheer power, the horse-power or the kilowatts of sounds was very difficult. The relations of power and steam, compressed air, coal, light, electric motors and generators, men, horses, the sun, tides, waterfalls, were well understood. They were sizable, tangible, interrelated and readily intervalued. Watts, kilowatts, horse-power, were terms readily associated with the above forms of power. But to measure sound waves in terms of watts and horse-power eluded the grasp of the instruments of the physicist and the engineer. One knew sounds were manifestations of power, but just how much power was a question not so easy to answer as in the field of horses and tractors and

boilers and hydraulic dams. To find the loudness of sounds apart from the human ear, to compare sounds objectively, was not a straightforward task. Lord Rayleigh developed the so-called Rayleigh disc for this purpose, but it was a fickle and whimsical piece of apparatus. Primarily, of course, the difficulty centered around the fact that the power, the watts, the horse-power or any other name equally horrendous and technical to the layman, was so small, so tiny, so microscopic, or rather micro-acoustic and even micro-micro-acoustic.

Horse-power and Kilowatts

A horse can, by a system of pulleys, lift a weight of 625 pounds, vertically upwards at the rate of six miles per hour. Such performance in 1775 was the basis of determining and establishing the magnitude of a horse-power by testing the horses drawing the wagons of the Nottingham, England, Brewery. That power was something one could understand; it was sizable, it was something to see, to sense, to appreciate. A 4,000-HP locomotive supplying power to pull a passenger train speeding through the night at 60 miles an hour must provide at all times a force of 25,000 lbs. A 1,000-HP motor can drive an airplane through the clouds at a speed of 200 miles per hour. All the time the propellers and their wind blasts have to push or pull with a force of 1,950 pounds. But a sound wave, intangible, invisible and evanescent, what is its power, its horse-power (perhaps "butterfly" or "aspen leaf power" would be a better term)? What is its thrust, its impinging force, its pressure?

So to make super-sirens in a war in 1942, one needed to know a lot of technique about loudness of sounds, rather to know about the power of sounds. Likewise one needed to know a great deal about the sensitivity, the acuity of the human ear. A great array of acoustic techniques have been accumulating during the last quarter century. Aristotle, Pythagoras and Galileo blazed trails long ago. Saveur, Helmholtz, Rayleigh, Barton, Miller, Webster, Crandall and Sabine continued to blaze trails. To-day the trails are widened and deepened. They have been blasted by the zealous research of another Sabine, of Knudsen, Stewart, Wegel, Watson, Frederick, Dudley, Wente, Steinberg, Lane and Fletcher.

To exert power, as engineers use the term, is to do something at a certain speed. The unit is the horse-power. A strong and powerful horse was found capable, as previously mentioned, of pulling with a force of 625 pounds at the rate of a brisk walk, six miles per hour. Just as surveyors measure distance in miles, rods and feet, so engineers measure power in horse-power and watts and kilowatts. A kilowatt is a thousand watts and a kilowatt is 1.34 horse-power. One watt is .00134 horse-power. In school days the 5,280 and 16½ used to make bothersome problems in arithmetic. The 1.34 number sometimes does the same in the arithmetic of engineering.

Mouth and Ears

The most common sound is speech. How much power in human speech? The sound waves coming out of one's mouth, talking in an average way, embody power; they are carrying an effect, the capability of affecting the human ear-drum. They bear power. It is a surprisingly small parcel of power; it is .000,000134 horse-power, or .00001 watt. This is quite below comprehension as a discrete amount of power. To say that the combined power of ordinary speech from the mouths of 5,000,000 people is equivalent to the power of a 50-watt incandescent light might give a vague notion as to how small it is. The finest technique of the alliance of electricity and sound was necessary to determine this value. In passing it is of particular interest to mention again that the mea-

surement of sound intensity has been accomplished via the route of electrical measurement. Microphones, amplifiers and thermophones have been the general instrumentalities.

If one shouts, the power of the sound is increased 100 times, namely, .001 watt or .0000134 horse-power. A mighty basso singing a mighty fortissimo may, for a short time, radiate a note of one watt (.00134 HP). A loud speaker at the stadium may be radiating a speech to 50,000 people, but the power of the sound is small, perhaps 10 watts (.13 HP).

The human ear is a sensitive and an acute sound detector. But just how tiny, how micro-micro-acoustic a sound can the ear hear? Again that was not an easy value to find, and of course varies with age and with people and with pitch of sound. On the average, however, modern technique has determined the value as .000,000,000,000,0001 watt (decimal point 15 ciphers one watt), *i.e.*, .000,000,000,000,000001 horse-power (decimal point 17 ciphers one horse-power). This value of sound intensity then becomes the value of the audible threshold of the human ear. It can be established as a sort of bench mark, a sort of sea level of sound intensity. Pike's Peak is 14,110 feet above sea level. So sounds in their intensity are nowadays compared to that minimum intensity which human ears can, on the average, hear, as the sea level of audition. In fact the term "level" is a good one. Sounds can be talked about very appropriately in their intensities as being at such and such a level. The zero level, the arbitrary comparison level, is that minimum sound intensity which the human ear can just hear.

Range of Speech and Hearing Intensities

Human beings can whisper and give out one ten-thousandth as much power (.000,000,00001 horse-power) and they can shout 100 times as loud as average speech (.00001 horse-power), a ratio of one million (1,000,000). That is, human beings can speak in sounds varying 1,000,000-fold in power.

In the realm of hearing, if sounds bear power of .001 watt (.000,001 HP), the ear is hurt by such a relatively large amount. This value of sound intensity might be called the threshold of pain. But it is in the range of sounds which a human ear can hear that it is such a remarkable device. Sounds varying ten million-million fold are sensed by the human ear without discomfort. The ten million-million fold is the ratio of .001 watt which produces pain to the .000,000,000,000,0001 watt which the ear can just hear. Great orchestras play fortissimos and pianissimos. These vary 20,000,000-fold in horse-power or watts. The aggregate power of their majestic music is but 75 watts, the power of a medium-sized incandescent electric light. The mouth and the ear are acoustic systems of our human bodies. They are both small power systems, as compared to walking, jumping and running. Yet the small amount of power in the normal speaking voice is, after all, many, many times more intense than is necessary for reception by the human ear. If the power embodied in the words of ordinary conversation could be parceled out in tiny bits just intense enough for a human ear to register, 100,000,000,000 could be made to hear. This is of course about 25 times more people than there are on the earth. An ordinary postage stamp is not a very ponderous object. If one had the time and inclination to cut a stamp into 50,000 bits and these bits could be dropped on the eardrum from about an inch above at the rate of 1,000 pieces a second, the ear would hear this lilliputian machine gun rat-a-tat-tat.

Sound Intensity Measurement

The subject of this homily is "Sirens and Bels." The reader quickly glancing at the title probably thought the printer had made a mistake, that it should be "Sirens and Bells" or perhaps even "Sirens and Belles." No, the word is

"bels" because the bel is the term (named, to be sure, in honor of Alexander Graham Bell) by which acoustical engineers measure the relative sound intensity of sirens, music and speech.

Mountain Levels and Sound Levels

The super-siren developed by the Bell Telephone Laboratories and designed and built by the Chrysler Corporation has elicited much interest lately. This discussion has been presented to help prepare the mind of the lay reader and the non-physicist not only to understand a bit about the Chrysler-Bell siren but also to appreciate the enormity of the sound it emits.

Mountains to be called mountains perhaps have to be at least 1,000 feet above sea level. But as mountains go, they do not vary a great deal relatively. Some Alleghany mountains are 4,000 feet and Mt. Katahdin in Maine is 5,200 feet. Mount Washington in New Hampshire is 6,300 feet. Among the Rockies there are some peaks 14,000 feet above sea level. Mt. McKinley is 20,000 feet and Everest 29,150 feet. So the highest mountain is only 29 times higher than the lowest mountain. Twenty-nine (29) is not a big number to say, and it is not a great number in numerical magnitude. The heights of mountains do not vary many fold, and therefore large numbers are not required to compare their altitudes.

But the levels of sounds which the ear can hear vary many, many-fold among themselves in the first place, and are individually a great many-fold greater compared to the audible threshold in the second place. Human ears can hear sounds varying in intensity ten million-million-fold. A shout is 1,000,000 times as intense as a whisper. A great orchestra radiates music rising and falling 20,000,000-fold. A thunderclap is heard by 50,000,000 people. Whenever sounds are talked about and compared, the numbers get awfully big. So the sound engineers (unlike the astronomers) not wanting to use such big numbers and scare themselves and perhaps the public, too, therefore said, after considerable deliberation: We won't use actual numerical values when we compare intensity of sound to the minimum level of ears, namely, .000,000,000,000,0001 watt—watts per square centimeter, to be completely explicit. We will do a bit of maneuvering and take a short cut. Instead of using the actual number we will use the number of decimal places in the number, if the number is less than 1, or the number of ciphers if the number is greater than 1. The number of decimal places and the number of ciphers will always be the same. One one-hundredth (.01) has two decimal places and one hundred (100) has two ciphers. So a watt of sound intensity would be an enormous number of times greater than the audible threshold detectable by the ear, .000,000,000,000,0001 watt. This number has 16 decimal places. One watt of sound would be 10,000,000,000,000,000 times as great. This number has 16 ciphers.

Ratios and Super-Ratios and Bels

Engineers, particularly acoustic and communication engineers, must have a general heritage of Scotch ancestry. So in this case to conserve words, breath and pencil, they discuss matters with their colleagues in terse fashion by agreeing that, instead of a lot of decimal places and a lot of ciphers, they will merely give the number of the decimal places or the number of ciphers and call them "bels." In the case cited they would say 16 bels. In the case of man shouting 100 times as loud as normal speech they would say 2 bels. If one sound intensity is 1,000,000 times as great as another he would say 6 bels. Such a procedure is very sensible as well as Scotch. It shortens conversation and it expedites exchange of ideas. In no wise does it inject a difficult-to-understand idea into the picture.

Sound intensity and other things, too, for that matter, are said to vary so many bels. "Other things" might be intensity

of radio signals, electric current and the relative distances of planets and stars. These vary a great many-fold, hence the use of the term "bel" would be appropriate. The variation of wages, speed of trains, heights of mountains and many other items in the welter of everyday life is generally small, so old-fashioned percentage is sufficient to talk about them.

Furthermore, if one has a lot of sounds whose power is expressed in bels above the level of the threshold, their comparison among the individual sound intensities is readily and simply arrived at. One siren has a sound whose intensity is 14 bels, a second 12 bels. Then the first is merely 2 bels louder. Now of course 2 bels greater means 2 ciphers, so if one wants to know more about the sounds, the first is 100-fold more intense than the first. But the engineer says that 100 is too big a number to think about. He suggests 2 bels. He has only subtracted 12 from 14 to get 2, which in turn means 2 ciphers, which means 100.

Bels and Decibels

One other point by way of exposition and then the sound intensity of the Bell-Chrysler siren will be readily understood. The engineer for various reasons decided the bel was even too great a unit, since 10-fold is 1 bel. Sounds which varied as much as a bel, namely, one cipher, was too big a variation—a 1000 per cent. variation in ordinary language. As feet are divided into inches which are 1/12th as long, bels are divided into decibels which are 1/10th as big. One might object and point out that "decibel" is a longer word than "bel" but that is not too much extravagance in ink. A siren which emits a sound intensity of 10 bels emits a sound of 100 decibels. If sounds vary as much as .1 bel, about 29 per cent. in actual value, the ratio is 1 decibel. So as a means of convenience, of terse conversation, of ready comparison, the acoustic engineer through fine measurement technique discusses loudness of sounds referred to the threshold value of human ears as sea or zero level. He always knows that the zero level, the reference level of sound intensity, actually embodies 10^{-16} watts. To find the power of other sounds is then a matter of simple arithmetic. Long rows of ciphers and decimal points are avoided. They are, however, cleverly indicated by the number of bels.

Chrysler-Bell Siren

With war and the airplane attack, therefore, came the problem of very loud sounds, of sirens and super-sirens. The problem could not be approached in casual, hit-and-miss, "haywire" manner. Guns, planes, ships and tanks require great engineering skill and techniques. Here, too, the approach had to be technical and scientific. Accurate mechanical design, compressed air, horse-power, watts, bels and decibels had to be carefully considered and acoustic acuity of human ears had to be known about to achieve real results.

The Chrysler-Bell super-sirens, one of which is atop the R.C.A. building in New York, have been generally accepted as being highly successful. The acoustical engineering figures about it, which might appear overwhelming and super-technical, are really very straightforward. The siren is entirely a mechanical contrivance, powered by a 140-horse-power gasoline engine, and uses compressed air. In no wise is it electrical. For many years in acoustical science, sirens, organ pipes, whistles and tuning forks have been the general means of producing artificial sounds. In recent years telephone receivers and loud speakers driven by vacuum tube oscillators have become the vogue. Always the siren has employed a perforated rotating disk through which puffs of air or steam escaped to produce sound. The Chrysler-Bell Victory Siren employs a 30-inch rotating plate with six holes which chop, of course simultane-

ously, the blasts of air from six throats, each about two inches square. A total of 2,500 cubic feet of air per minute at a pressure of 5 pounds per square inch is driven out of the six throats. The "chopper" rotates at 4,400 revolutions per minute. The pitch of the sound is 440 vibrations per second.

It is appropriate to observe that although the siren is a mechanical device and sound waves are mechanical waves, all the techniques of measurement to determine whether the raucous sound produced by the Chrysler-Bell siren is effective are electrical. (See Fig. 1.)

A Super Stentorian Shout

The mythological Stentor had "a cry as loud as the cry of fifty other men." The Victory Siren has a "cry" equal in power to 4,000 million ordinary men or eighty million Stentors. These amazing comparative numbers result from straightforward considerations.

The sound power out of people's mouths is .00001 watt (10^{-5} watt). The aggregate sound power out of a giant loud speaker at a stadium might be 10 watts. The loud speaker aboard a boat which directed traffic at the international yacht races at Newport in 1934 emitted 500 watts (.67 HP) of aggregate sound power in the form of highly intelligible speech. This was one of the largest loud speakers that ever had been built.

The Chrysler-Bell siren's power in the form of a raucous sound is 42.2 kilowatts (56.5 HP). This siren then produces probably the most sound power ever artificially and continuously generated. Its sound is more intense than a thunderclap and various other extra-loud sounds. Close to the siren, the sound is not only powerful but dangerous, too. (Fig. 2.)

It is to be noted that the "total sound power" radiated by the Chrysler-Bell siren is 42.2 kilowatts. Of course such an enormous amount of sound does not come from a tiny aperture. Sound never comes from the theoretical point source. Actually the equivalent aperture of the super-siren is a circle 28 inches in diameter. Out of the big aperture all the 42.2 kilowatts of sound can be thought of as pouring.

As has been said, sound waves, light waves, radio waves and heat waves embody and carry power. Out of the equivalent 28-inch circular aperture of the super-siren comes 42.2 kilowatts of power. The midday July sun sends to the earth heat waves which are very warm. Actually the sun's radiation on an area of the earth's surface equal to the siren's aperture is only ½ kilowatt of heat wave power. The total power of the siren's sound radiation from the entire aperture is 42.2 kilowatts, and from a small area a bit larger than an aspirin tablet the intensity of sound radiation turns out to be 10 watts. So the calculation of the intensity of the sound compared to the threshold (10^{-16} watts) is very simple and straightforward. Ten watts equals 10^1 watts. 10^1 watts divided by 10^{-16} watts equals 10^{17}. This is then a ratio of intensities of 17 bels and of course 170 decibels. Of course this means that the intensity of sound from the super-siren is almost a million times a million times a million greater than that perceptible by the human ear. If it were 18 bels (180 decibels) instead of 17 bels (170 decibels), it would be the million times a million times a million ($10^6 \times 10^6 \times 10^6 = 10^{18}$).

With testing apparatus such as is shown in Fig. 1, it was found that at a distance of one mile the siren produced a sound of 100 decibel level, or 10 bels or one with 10 ciphers following greater than the threshold of audibility. Calculations indicate the sound level at 20 miles would be 60 decibels (6 bels) equivalent to that of ordinary conversation. At 75 miles, calculations reveal that the level would be about that of the threshold, in other words, just audible.

The sound intensity of the super siren is 4 bels (40 decibels) or 10,000

times greater than the threshold of pain. It is the most intense sound ever continuously produced by the techniques, the accurate knowledge and the manufacturing skill of man. Its only rival in intensity was the explosion of the volcano Krakatoa in the East Indian Ocean in 1883. It is recorded that the sound of that explosion was heard 3,000 miles away. It must have been many times louder than the Chrysler-Bell siren, since it is estimated that the siren could be heard, under favorable conditions, only 75 miles.

Intensity and Totality

Perhaps the reader has observed the repeated use of the phrase "sound intensity." To be accurate and explicit, in the discussion of sirens and sounds the engineer uses this phrase advisedly. "Bels" and "decibels" are used not to compare sounds—the total power of sounds—but rather the intensity of sounds. Of course the siren must send out a great deal of sound, but, more important, it must emit a very intense sound. As observed in the chart of "Sound Intensities" ordinary speech directly into the ear is more intense than a lion's roar at a distance of 18 feet. Of course the lion's roar embodies more sound than does speech, but the ear has no way of knowing how much sound is about; the ear can only give notice of how intense a sound is. Of course if the head is turned in a lot of directions and the ear hears considerable intensity at many angles, then of course one knows there is a lot of sound. It is therefore not completely correct to say, the Chrysler-Bell siren produces 17 bels (170 decibels) of sound. It does produce 56 horsepower of sound, but this amount of sound spreads out over a great area. Of course a siren must produce a great deal of sound, but likewise it must produce a very intense sound. It is more correct to say that the sound intensity of the siren is 17 bels.

In the days of the elevated in New York, not only was there a great deal of noise at 34th Street and Broadway, but also there was a deafening intensity of sound. At a baseball game in the Yankee Stadium there is at all times a great totality of sound, but not a great intensity of sound. This totality would not be measured in bels. All about us during the day, there is a lot of light—a really very large amount of light—but the intensity of daylight does not blind us, except when we look directly at the sun. A great modern searchlight pierces the sky at night with a brilliant, intense beam, but does not light up the landscape. The pantoscopic moonlight is not intense but does flood the entire country-side with a totality of light sufficient for reasonably good vision.

The pantosonority of a sound source is expressed in horsepower or kilowatts. The ratio of the intensity of sound produced at a given place, as compared to the minimum intensity perceptible by the human ear, is measured in bels and decibels. As shown in the chart, intensity of sound is completely specified in absolute —not relative—terms, by knowing the power per unit area—the watts per square centimeter. Horsepower per square inch would be another way to express it. Intensity is appraised by human ears and electrical ears (microphones). Totality is appraised by the integration of the brain.

So it can be accurately said that the Chrysler-Bell siren produces not only an amazing totality of sound but also an amazing intensity of sound.

Maximum Theoretical Intensity of Pure Tone

One might speculate as to the most intense sound that theoretically could be produced, that is, the most intense pure tone, a tone such as a good tuning fork tone. Of course the pressure of the air in the sound wave varies. That is what makes it a sound wave. The greatest

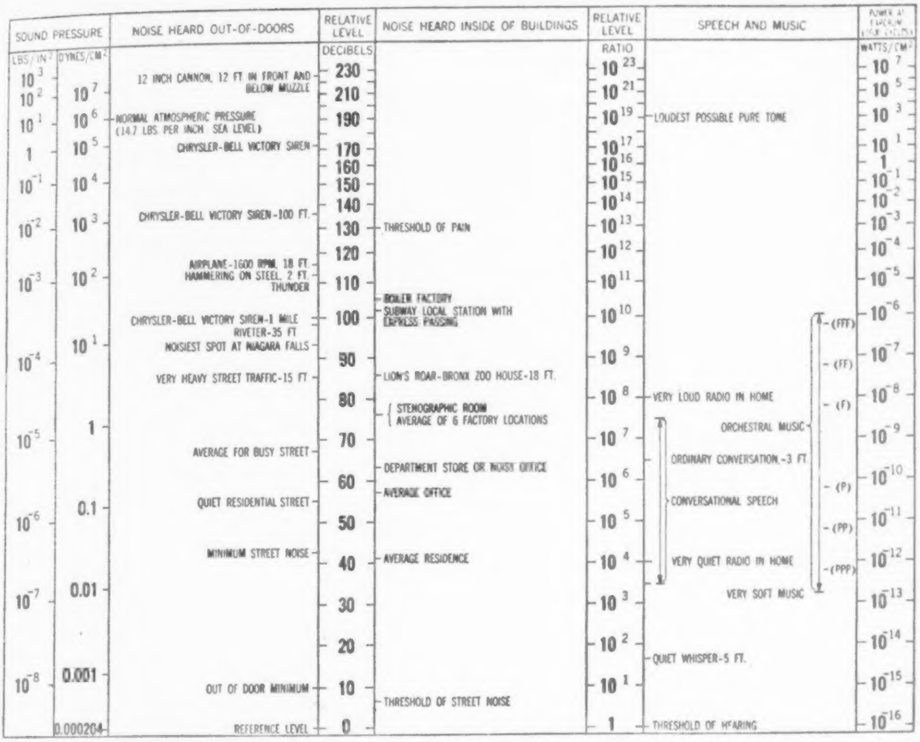


FIG. 3. INTENSITIES OF A NUMBER OF DIFFERENT SOUNDS

deviation below atmospheric pressure would be a vacuum—14.7 pounds per square inch less than normal. For a pure tone, then, the maximum pressure at a particular instant of time in the intense sound wave would be just double the atmospheric pressure, 29.4 pounds per square inch. This theoretical maximum intensity of sound would require a radiation from the area of an aspirin tablet of 1,000 watts instead of the 10 watts of the super-siren. The sound intensity would then be 19 bels (190 decibels). Of course the Krakatoa sound was not a pure tone. Its sound power must have been hundreds of kilowatts and its intensity many bels. The maximum pressure in its sound wave must have been many, many-fold greater than atmospheric pressure.

The pressure of tiny bits of postage against the eardrum was previously used to indicate the delicacy of response of the eardrum. Actually, in terms of pounds per square inch pressure on the eardrum, the value of ear threshold of pressure sensitivity is 3.5×10^{-9} pounds per square inch. The pressure in the sound waves at the aperture of the super-siren is calculated to be one pound per square inch.

Radio Waves and Sound Waves

To get 42.2 kilowatts (56.4 HP) into the sound waves radiated by the super-siren has been a fine achievement of mechanical design and compressed air technique. It was not a simple or easy task. It is provocative to realize that it has been much easier generally to put wave energy into the form of electric waves, radio waves, and send them out from an antenna. The 50,000 watts of a broadcasting station appears very big, and is the subject for a bit of boasting. In fact, 50,000 watts is only 80 horse-power, and 80 horse-power auto engines

are considered small and exist in great numbers. So in the general welter of the world's work 80 horse-power items are not big or extraordinarily powerful, but in radio engineering 80 horse-power transmitters are so regarded. In acoustical engineering, 80 horse-power would be a gargantuan value.

Some transoceanic radio telephone transmitters radiate about 75,000 watts or 100 horse-power. The super-siren puts a terrific and ear-splitting sound into the air with 56 horse-power. An everyday environment of sound of 800 Chrysler-Bell sirens scattered over the United States (the number of radio broadcasting stations in America) all day, would be unbearable. For short periods they serve excellently as an air-raid warning. Yet we move about comfortably close to radio antennas while powerful radio waves are impinging upon us. It is fortunate that humans have no radio ears, only acoustic ears.

Calculations indicate that the Chrysler-Bell siren can be heard 75 miles. Radio telephony across 3,000 miles of ocean is an everyday commonplace. Could a siren or a loud speaker be made so sonorific that it could be heard across the sea? Indeed it would be a terrible noise! The likely answer is "No." Furthermore a sound wave would require 4 hours to go across the ocean. Facile conversation would not be possible under attendant time delays. Only exploding volcanoes are heard 3,000 miles. Explosions of 12-inch modern cannon produce a sound intensity of 230 decibels (23 bels) at 12 feet; at this distance, the sound-wave pressure is about 500 pounds. They are heard across the English Channel, but perhaps 100 miles is the maximum range of their sound. The radio transmitter goes about its fine job with the passerby unaware. Radio apparatus and radio waves surely have many talents.

The intensity of the sun's heat waves on the earth's surface have been mentioned and are considerably lower in power content than that embodied in the sound waves at the equivalent radiation aperture of the Chrysler-Bell super-siren. It is interesting to ask what is the intensity of power in a radio wave necessary in radio transmission. For good reception by a good type of radio receiver, the radio wave power intensity arriving at one's receiving antenna should be at least 10^{-9} watts. This is quite a bit of wave power compared to the tininess of sound intensity which a human ear can hear, namely, 10^{-16} watts. It is 7 bels greater. Figuratively, human ears, then, could be said to be 7 bels more sensitive than an electrical ear, namely, 10^{7}, or 10,000,000-fold.

If very special antenna arrangements and very special radio receivers and vacuum tube amplifiers are used, as they are in transoceanic radio telephony, then the intensity of power in a radio wave can be less. In this case, the intensity of radio wave power can be as low as 10^{-19} watts and good results obtain. This 10^{-19} watts is 10^{3}, 1000-fold, or 3 bels less than the threshold intensity of the human ear.

Inspection of the chart, Fig. 3, will reveal a lot of interesting ideas about sounds, speech and music. It is to be continually remembered that sound waves are an embodiment of power and that the power of the sound in a just audible sound is the sea level of comparison for other sounds and that other sounds are so many, many times louder that, for purposes of easy calculation, ratios must be talked in terms of the decimal places and ciphers instead of the actual number. These decimal places and ciphers gave rise to the simple and convenient language of bels and decibels.

The alliance of acoustical science and techniques and mechanical engineering design and skill has given notably fine results. One thing is sure, the acoustical engineer has made the sound wave the Paul Revere of World War II.

FLIGHT IN THE DARK: A STUDY OF BATS

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FOR almost exactly one hundred and fifty years an unsolved problem has occupied a special niche in the minds of certain men of science. What type of sensory perception—what sense organ—informs flying bats of the location of obstacles to their flight? In the pitch blackness of the caves they inhabit, the eyes can be of little or no use for detecting objects; yet the location of ceiling, walls, etc., undoubtedly are perceived with ease and accuracy. The purposes of this essay are to cite some of the many attempts which have been made to resolve this problem, and to describe the experiments by which Dr. Donald R. Griffin and I have arrived at what we believe to be a simple and adequate explanation of the phenomenon.

In 1794, when the study of natural phenomena was burgeoning as never before, Lazzaro Spallanzani first recorded observations on the flight of bats. Having put out its eyes, he freed an animal in a closed room. It at once flew off and avoided walls, the ceiling, silk threads and "whatever other bodies which may have been placed about in an effort to embarrass him." Clearly these animals were equipped with a non-visual mechanism of amazing efficiency for detecting obstacles, and to the discovery of this mechanism Spallanzani directed his talent for devising simple yet fruitful experiments.

He eliminated, in order, the senses of touch, smell, taste and hearing. So far as could be observed, none of these treatments led to a significantly decreased ability to avoid, and consequently, he proposed that bats may possess a sixth sense whose nature is unknown and unknowable.

But contrary to what most people believe, Spallanzani did not maintain this point of view for very long. At his own request, the experiments were repeated by Louis Jurine, a Swiss entomologist, with very different results. Jurine found that bats with *plugged ears* invariably blundered helplessly into the same obstacles which were avoided with ease upon removal of the plugs. Therefore, according to Jurine, the ears directed bats—and Spallanzani promptly agreed. He happily discarded his theory of a sixth sense and accepted Jurine's explanation without reservation.

Meanwhile, Georges Cuvier advanced and warmly advocated the theory that bats possess in their wings an exquisitely developed sense of touch which, alone, was responsible for informing the flying animal of the location of obstacles. This hypothesis had received very careful experimental consideration from Spallanzani and his colleagues only to be rejected as an impossible explanation. Although Cuvier himself recorded no experiments in support of his theory, he clung to and reiterated the proposition with surprising tenacity. Upon reading any discussion by Cuvier on bats, one finds there a spirited refutation of the ideas of Spallanzani and Jurine and an assertion of the experimentally disproved touch theory.

The weight of Cuvier's authority has led scientific men ever since to conclude that (1) Spallanzani's work was haphazard and uncontrolled, (2) Spallanzani continuously supported the theory of a new sense, and (3) the bat detects obstacles by a sense of touch. None of these conclusions is correct. A complete discussion of the first two is the subject

of another article;[1] a rational explanation of the method used by flying bats to detect obstacles is the subject of the rest of this essay.

When Donald R. Griffin and I attacked the problem of obstacle avoidance by bats, we had at hand the results of many experiments performed since the time of Spallanzani. In practically every one of these, only qualitative results were described. Some impairment of ability to avoid was claimed to follow destruction of any sense organ, although it seemed clear that bats were most inexpert when their ears were plugged. Since, however, the exact degree of impairment of a given sense organ had never been stated in quantitative terms, we decided to measure the performance of bats in an obstacle situation whose characteristics were known and reproducible, to collect our data in a standard way, and to analyze our results by a rigid statistical test.

Furthermore, adequate consideration had never been given to the injury incident to elimination of the sense organs. Aside from the obvious fact that an injured animal is not likely to perform as well as an uninjured one, drastic operations make it impossible to restore the bat to normal in order to retest its performance. We planned, therefore, to render our bats blind, deaf, etc., in a strictly reversible manner, and to test the animals in the obstacle situation while normal, while blind or deaf and finally while normal once more.

The room we selected for the tests is a soundproof chamber in the Cruft Physics Laboratory at Harvard. Its dimensions are fifteen feet by eleven feet by eleven feet high; and the walls, ceiling and floor are well padded with soft sound-absorbing material. In a straight row across the center of this room, spaced one foot apart and hanging vertically from ceiling to floor, we suspended a row of steel wires. We selected wires with a diameter of one millimeter because this size has been shown to be about the smallest which bats can avoid. We hoped in this way to make our barrier difficult for even a normal bat to maneuver through, and thus to show up any impairment of ability in the operated bats at once.

A bat set free in this room would fly back and forth from one half to the other through the barrier of wires. As the animal did so, a count was kept of the number of times it hit and missed the wires. Each hit or miss was considered a trial. There was rarely any difficulty in judging these hits and misses, for when the bat struck, even very lightly, the observer could usually hear the noise caused by the contact of wing on wire and see the wire obstacle move back and forth under the impact.

In order to obtain data legitimate for analysis by statistical methods, it was necessary to make a large number of observations on each animal. A minimum of fifty passages through the barrier was found to be convenient and adequate for this purpose, but whenever possible more trials were recorded. The performance of the animal was then reduced to a score expressed as percentage of hits in the series of trials; if, for example, the bat hit the wires twenty-five times while passing through a total of seventy-five times, its score would be thirty-three per cent. A high score, therefore, indicates poor ability to avoid, while a low score indicates good avoiding ability.

Most normal bats when set free in the experimental room would fly back and forth, circling, swooping and dodging as if thoroughly at home. When their individual scores were determined, however, it was clear that some animals were much more adept at avoiding collisions than others.[2] Thus, of 129 *Myotis l. luci-*

[1] "The Avoidance of Obstacles by Flying Bats: Spallanzani's Ideas (1794), and Later Theories," by R. Galambos. *Isis*, 34: 132–140, 1942.

[2] For complete description of methods and results, see D. R. Griffin and R. Galambos, *Jour. Exp. Zool.*, 86: 481–506, 1941.

fugus tested, the lowest score (per cent. hits) was 7 per cent., the highest 65 per cent., and the average 35 per cent. We were apparently measuring a highly developed skill which reached its fullest expression in only a few animals.

In the next experiments we blinded the bats. This was accomplished in a painless manner simply by covering the eyes with a dark-blue solution of collodion; when, during the course of a minute or two the solvent evaporated, it left behind a hard layer of collodion through which the animal could not see. The collodion layer could be quickly removed with a wad of cotton soaked in ether, to restore sight to the animal.

Twenty-eight blind bats collided with the wires an average of 24 per cent. of the time, as opposed to 30 per cent. when completely normal. From these figures it is clear that blind bats are as adept in avoiding obstacles as normal ones. Some of them, in fact, showed marked improvement after being deprived of their eyesight, a phenomenon which appears to demonstrate that under certain conditions a bat's eyes are more a hindrance than a help.

Having thus substantially confirmed Spallanzani's original observations, we next set about to repeat the experiments of Jurine on the ear. To deafen a bat we at first used one to two techniques: (1) the ear flap was turned down and sewed to the head; (2) a drop of the collodion was placed in the ear and allowed to harden. Depending on which technique was being used, hearing was restored by cutting the threads holding the ear-flap or by poking a hole in the collodion.

Our deaf bats could not avoid obstacles. The average score of twenty-one deaf bats jumped from 28 per cent. when normal to 66 per cent. when deaf.[3] But the difference in these scores by no means portrays adequately the behavior of a deaf bat. The light touch of the finger which frightens a normal animal into quick, graceful flight has no effect whatever on deaf ones; they must be prodded with a stick. They are extremely reluctant to leave their perch and upon doing so flutter slowly and heavily through the air until they strike the walls, the wires or the experimenter. After the collision they continue fluttering helplessly, fall to the floor and there begin at once to scratch at their ears. The bewilderment of the deaf bat is complete.

All deaf bats recovered as if by magic when the use of their ears was restored to them, and their scores dropped at once to normal.

Cuvier and others have criticized experiments such as these on the grounds that the poor flight of the deaf animal is due to injury accompanying the deafening process. We believe this criticism is effectively answered by the demonstration that deaf bats perform normally when their hearing is restored to them, but to provide a final answer the following experiments were performed. Small glass tubes were fitted tightly into the external auditory canal and sewn firmly in place. Bats so equipped could hear only those sounds which passed down the inside of the tube, and by plugging this, we could cause deafness without further injury. The average score of eight bats, with unplugged tubes in their ears, was 32 per cent. This score is surprisingly low, considering the drastic change in shape of the auditory passageway caused by the glass tube. When the animals were made deaf by plugging the tubes with cotton threads, their average score rose to 67 per cent., and all the symptoms previously observed in deaf animals ap-

[3] We have determined what score might be expected from a bat completely unaware of the wires, by calculating the number of times an inanimate object with the average dimensions of a flying bat would strike if thrown at random at the barrier. A reasonable estimate is 65 to 70 per cent.

peared at once. Upon removal of the threads, each bat immediately returned to its previous level of performance. Since throughout these experiments, any injury or irritation was constant, we were forced to conclude that blocking the air passage to the bat's ear was solely responsible for the loss of dexterity in avoiding.

Having arrived at this conclusion, we turned to a suggestion advanced in 1920 by Hartridge. He proposed that the bat avoids by emitting sounds which echo off from obstacles and return to the ears, where these echoes give rise to appropriate sensations which inform the animal of the location of the obstacle. If this should be the explanation, we argued, then preventing bats from making sounds should render them just as helpless as plugging their ears. For if both sound production and sound reception are involved, elimination of either must lead to the same result.

We therefore tested bats which were unable to make sounds. They were rendered mute simply and quickly by tying thread around the snout while the jaws were closed. To make certain that no sounds whatever could issue from the mouth, we also coated the space between the lips with collodion. Eight bats, perfectly normal except that they could not open their mouths, were completely helpless when set free to fly. They fluttered slowly and cautiously about, turning and twisting, but eventually blundered into the wall or wires and fell to the floor. They were obviously just as inept at avoiding obstacles as their deaf brothers had been, and their average score was about the same (65 per cent.). When the threads around the mouth were cut, they at once flew off, swooping and gliding in a perfectly normal manner, and avoiding the wires with their previous skill.

Needless to say, these results excited us greatly. We were satisfied that the animals were uninjured, able to breathe adequately, and fully possessed of all faculties except speech. It is common knowledge that flying bats only rarely emit audible sounds, and yet our results clearly indicated that they used sounds to direct themselves. This could mean only one thing: bats in flight emit and direct themselves by sounds which we can not hear. Tests were in order, therefore, to see whether this was so.

Man perceives, as sound, frequencies of air vibration lying between about twenty and twenty thousand vibrations per second. These limits are apparently placed upon the human organism by the mechanical properties of the ear, and "sounds" with frequencies both above and below the limits of human hearing are known to exist. Below twenty cycles per second, air vibrations are "felt" rather than heard, and above twenty thousand cycles tones are too shrill to be audible. By definition, sounds above the upper limit of human hearing are called supersonic sounds. They can be detected by a variety of methods, the most convenient of which uses a thermionic amplifier to convert the supersonics into sounds we can hear. Professor G. W. Pierce, at the Cruft Physics Laboratory, is a specialist in the study of supersonics, and it was to him that we turned for the apparatus for our next experiment.

We borrowed from him one of the amplifiers which translates supersonic into audible sound. We placed it in our wire-strung experimental room and liberated a bat. The machine immediately gave out a great chattering clamor which continued so long as the animal was in the air. When the bat lighted on the wall, the chattering stopped, only to begin again when the animal took wing. We repeated this observation again and again with the same striking results. There seemed now little question that bats directed themselves through mazes of obstacles by using reflections of supersonic cries.

In order further to implement this explanation, we made a study of these

supersonic cries. We found them to be emitted by more than one hundred bats of four different species, thus amending the earlier statement of Pierce and Griffin that flying bats do not emit supersonic cries. The supersonic cries, furthermore, usually appear entirely independently of the audible cry and consist of a band of sound frequencies in the region of fifty thousand cycles. Each bat, we found, has a supersonic voice peculiar to itself as regards which frequencies are emitted and their relative intensities. The duration of each cry is very brief, being less than one fiftieth of a second long. Bats on the wall, preparing to fly, produce fewer than ten cries per second, but when in flight and especially when the animals approach an obstacle, the cries are emitted at astonishingly high rates.

The most important support for the theory that the cries play a part in the obstacle-avoiding mechanism comes, however, from the fact that just before normal bats successfully fly past the wires an abrupt drop in rate of emission of cries takes place. The drop—from about fifty to about thirty cries per second—is sudden and unmistakable. In cases where the bat strikes the wires, this drop is rarely observed. And when deaf bats fly, the drop in rate never takes place; in fact, deaf animals keep up a constant succession of cries at a single monotonous rate all the time they are in the air.

The question at once arose as to the source of the supersonic cries. Tying the mouth shut renders bats incapable of avoiding obstacles, as we have already seen; this is clear evidence that the sounds issue from the mouth. To make certain of this point we liberated mute bats in the room containing the supersonic detector and found the cries to be reduced to a very feeble intensity. We then demonstrated that the supersonics issue only from the mouth by immersing all except the head of a normal bat in water; the cries were very loud. When we immersed only the head, on the other hand, no supersonics could be detected in spite of the violent struggles of the animal.

The production of supersonic sounds by animals is a matter which has received practically no study, chiefly because of the technical difficulties involved. Certain insects have been shown to make supersonic sounds, but they appear usually to be merely accidental by-products, *i.e.*, harmonics, of the audible chirp. Almost nothing is known about high-frequency sounds in mammalian cries. We were naturally interested to discover the way in which the bat cries are produced, and to this end we consulted the literature for anatomical studies on the bat larynx. We found, in a paper by Elias,[4] a complete description of this organ taken from species related to ours. Elias, writing over thirty years ago, was astounded by the excessive development of the larynx in bats. The laryngeal cartilages have become almost completely ossified, and extremely large muscles are attached to the voice box in such a way that their contraction must lead to great tension on the vocal cords. The vocal cords are different from those in most mammals, being very short and tough, and extremely thin. Elias concluded that all the morphological peculiarities of the larynx are directed toward increasing the pitch of the cry emitted, and that from the anatomical point of view there is every reason why the bat audible cry should be a very shrill squeak. From the way he writes, we feel confident that if he were told bats actually emit sounds of such high pitch as to be inaudible to man, he would not be in the least surprised.

Let us recapitulate briefly the evidence so far advanced for the auditory theory. (1) Bats can not avoid obstacles if deaf or if unable to use their mouths. (2) Bats give voice to supersonic cries. (3) A characteristic change in the rate of production of the supersonic cries occurs

[4] H. Elias, *Morph., Jahrb.*, 37: 70–119, 1907.

when bats avoid obstacles; this change is almost always absent when normal bats strike the obstacles, and it never occurs when deaf bats fly about. These facts can be explained by the auditory theory alone, but with them its proof is not yet complete. For a fully adequate solution, evidence is required that bats hear sounds which lie in the supersonic range. This evidence has been obtained by recording cochlear potentials from bats in a way which will now be described.

The ear of mammals has three separate chambers, named, in order from the outside in, the outer ear, the middle ear and the inner ear. The inner ear is more commonly known as the cochlea, a spiral of thin bone containing extremely complex structures which actually analyze sounds.[5] The most important of these structures are probably the cells which lie on what is called the bacilar membrane. These cells, called hair cells, are set into motion by the sound waves which have been conducted to the cochlea from the outside air, and in some as yet unknown way they initiate the impulses of the auditory nerve which, upon arrival at the brain, are eventually interpreted as sounds. The hair cells, thus charged with transforming physical vibrations into the stuff of which sensations are made, form an important link in the chain of events which is the concern of the auditory physiologist.

Some years ago, it was found that when sounds fall upon the mammalian ear, electrical oscillations arise in the cochlea. These oscillations, called cochlear potentials, have been traced to the hair cells, and it is now commonly agreed that the site of origin of cochlear potentials is the stimulated hair cell. In order to orient the reader to the somewhat complicated technique of measuring these potentials, it will be advisable to describe briefly the standard technique for obtaining and recording them.

The cochlea of an anesthetized animal is exposed and a strand of wire is placed against it. Another wire is placed in contact with indifferent tissue—usually the skin underlying the incision. These two wires, called electrodes, lead to an amplifier which magnifies potential differences and activates some type of recording system (loudspeaker, galvanometer, etc.). Differences in potential occur between the two electrodes whenever sounds are presented to the ear, and it has been found that these potentials duplicate the wave-form of the sounds with a high degree of accuracy. Thus if one speaks into the ear of the animal, the voice is clearly recognized as it issues after amplification from the loudspeaker. The same fidelity of reproduction occurs when pure tones are presented, and the entire phenomenon disappears when the cochlea is destroyed, its circulation impeded, or when the animal dies.

The relation of the electrical activity of the cochlea to hearing is still somewhat obscure. The sensation of hearing clearly involves many more factors than the changes taking place in the auditory end-organ, and the question has been raised, therefore, as to whether the mere demonstration that cochlear potentials arise when a sound is made is sufficient evidence that the animal hears the sound. Attempts have been made to settle this point, and, although they have not led universally to the same conclusion, it may be stated that animals probably do perceive only those sounds which cause cochlear potentials. The best experiments, for instance, show that cats and dogs respond to sounds up to about thirty-five thousand cycles or so, and it is possible to record cochlear potentials in these forms up to, but not much beyond, thirty-five thousand cycles. Studies of this sort have never been made on bats.

[5] In this discussion I follow the interpretations of S. S. Stevens and H. Davis in their book "Hearing," published in 1938.

To measure cochlear potentials in bats, a supersonic generator which produces pure supersonic tones, and a supersonic microvoltmeter capable of detecting and measuring high frequency cochlear potentials, were put at our disposal by Professor Pierce. We have been able to demonstrate that the bat cochlea produces potentials having the same frequency as the sound wave for sounds up to at least ninety-eight thousand cycles.[6] The apparatus used can not measure potentials of higher frequency than this, and there is every reason to believe the bat cochlea can convert sound into electrical waves for still higher frequencies. Cochlear potentials have previously never been observed in mammals to sounds above thirty-five thousand cycles. Our results, studied in more than thirty bats of four species, clearly offer strong support to the theory that bats hear supersonic sounds, for it would be a remarkable coincidence indeed if the highly unusual electrical properties of the bat cochlea were not in some direct way connected with an ability to perceive supersonic cries.

It is significant to note that this result was recently predicted on anatomical grounds. Ikeda and Yokote, two Japanese investigators, concluded from their study of the Japanese bat, first, that the bat cochlea is unique among mammals in having extraordinary morphological peculiarities in that region of the basilar membrane which is excited by sounds of high frequency, and second, that these peculiarities are of such a nature as to make it very likely that bats hear very high-pitched sounds. They tried to establish this point by experimentation, but failed due to technical difficulties.

Auditory Theory of Bat Obstacle Avoidance

We have seen how three lines of experimental evidence converge upon the auditory theory as an explanation for bat obstacle avoidance. In the first place, bats can avoid obstacles only so long as they have the use of their mouths and ears; if the ears are plugged or the mouth tied shut the animal performs as if with no perception whatever of obstacles in its path. In the second place, the flying bat not only produces cries inaudible to man, but in normal bats a correlation is demonstrable between the way in which the cries are produced and the location of the bat with respect to obstacles. This correlation is not shown by deaf bats or by normal bats which strike obstacles. Finally, the bat cochlea generates potentials when supersonic sounds are presented to the ear, a property not possessed, at least not to so high a degree, by any other known mammalian auditory organ.[7]

This experimental evidence can not be adequately explained by any theory other than the auditory theory. It will be necessary, therefore, to present this theory in a more specific way.

We propose the following as a résumé of the auditory theory. The supersonic cry of the flying bat permeates the space through which the animal will presently fly. Objects in that space scatter the sound waves, some of which then return to the ears of the animal and are perceived as sound. Some characteristic of the pattern of the reflected waves indicates to the animal the precise location of the objects, and it then suitably alters its course so as to avoid them.

Many statements in the preceding paragraph could profitably be amplified. It would be interesting, for instance, to

[6] R. Galambos, *Jour. Acoust. Soc. Amer.*, July, 1942.

[7] In addition to these three lines of evidence, the auditory theory receives support from the descriptions of the bat larynx by Elias (footnote 4), the bat ear by Ikeda and Yokote and the bat brain (by Poljak). Poljak (*Jour. Anat.*, 60: 465–469, 1925), characterizing the cochlear nuclei in the bat brain as "excessively large" and the optic tracts as so reduced as to be almost vestigial, concluded that all the anatomical facts pointed toward a marked dominance of the sense of hearing in bats.

demonstrate just how the remarkable ability of bats to avoid obstacles arises in part out of peculiar directional and reflective properties of supersonic sounds, and to point out how if bats were to use audible sounds this would lead to a very much reduced ability to avoid. But only one statement will be treated here; namely, that some characteristic of the pattern of the reflected waves indicates the location of the obstacle. What is this characteristic, and how does it serve its important function?

There appear to be two ways in which the bat might be informed of the exact location of the obstacle. Let us assume the animal flies head-on toward a wire; the echo from the obstacle will arrive at both ears simultaneously. If the head should be turned slightly to one side or the other, however, the path traversed by the sound would be slightly longer for one ear, and the sound would therefore strike the near ear a fraction of a second before it arrived at the far ear. The bat, having presumably learned by long experience, would know at once that the obstacle lies on the side of that ear which first perceived the sound. In order to locate the obstacle exactly, it would then turn its head so as to receive the echo simultaneously in both ears. If the bat located obstacles by this method, it would be using as a cue what is technically known as the difference in time of arrival of the sound at the two ears.

But there is another possibility. Let us suppose the bat approaches the wires with its head turned slightly to one side. The echo would travel to the near ear by a free, unobstructed path. The far ear, on the other hand, with the snout and head interposed between it and the wire, would lie in a "sound shadow" cast by these structures. This would simply mean that the sound intensity at the ear in the shadow would be less than that at the other ear, and the bat could locate the wire by orienting its head so that the intensities at both ears were the same. It would thus localize the sound source by the so-called intensity difference method.

Either of the above explanations is a likely description of the auditory mechanism by which bats locate obstacles,[8] and there appears to be no way at present to evaluate them. It would be convenient here to resort to the subterfuge commonly used by biologists when faced with a problem of this sort; namely, to render a judgment in a particular case by citing experiments on other animals where the given phenomenon has one and only one explanation. Unfortunately, it is not possible to lean on such a device here. Dogs, cats, birds, etc., are known to possess remarkable powers for locating the exact sources of sounds, but no one has yet shown that time difference, not intensity difference (or *vice versa*), is the sole explanation. Lacking even this type of evidence, therefore, we must conclude that time difference, or intensity difference, or both, constitute the mechanism whereby bats determine the precise location of obstacles in their path.

This uncertainty does not weaken the auditory theory in the least. The exact cue is, after all, a matter of subsidiary importance, however interesting it may be in itself. Bats possess anatomical structures which are peculiarly adapted for producing and receiving supersonic sounds; they emit supersonic cries when in flight, and they can not avoid obstacles if their ears or mouths are covered. Regardless of how one may choose to arrange these facts, he is driven to conclude that the ears serve to direct the bat as it flies in the dark.

[8] Localization by the difference in phase method is extremely unlikely because of the short wave-lengths involved. See Chapter 6 of the author's doctoral dissertation, "The production and reception of supersonic sounds by flying bats," on file at Widener Library, Harvard University, Cambridge, Massachusetts, for a complete discussion of these matters.

CALENDARS AND CALENDAR REFORM

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SOMETIME we shall be called upon to reshape the organization of the world so as to insure a lasting peace and promote the general welfare of mankind. It is well that we begin to think about that reorganization and to consider what changes, if any, would contribute to the welfare and happiness of mankind in general, for isolation is no longer possible for any part of the globe or any section of the human race. Our destinies have been for all time united by science and invention, which have diminished the distances between continents. One of the devices which make possible an orderly existence of men in social groups is the calendar.

The calendar by which we measure the passage of time and the recurrence of the seasons possesses several serious defects capable of remedy, if all men could reach an agreement as to what changes are desirable, and the proper time for making them. This, however, is not easy of attainment, for our present calendar is one of the basic structures of our civilization and such structures are not easily changed. They constitute the framework of all our social institutions, which has reached its present state by a long process of evolution, and such a framework, age old in its development, should be altered as little as is consistent with progress.

All peoples who have engaged in agriculture of even the most primitive sort have felt the need of a system for measuring time and predicting the recurrence of the proper seasons for planting and harvesting crops. Around an agricultural calendar they have arranged a program for religious rites, feasts, dances and other celebrations designed to influence and propitiate the unseen powers thought to control natural processes.

The most obvious means for measuring time are the movements of the heavenly bodies, sun, moon and stars. A calendar based on one or more of these has regularly been formulated by a primitive people emerging from barbarism.

The most conspicuous of the heavenly bodies, the sun, not only defines the year from one seeding time to the next, but also from one sunrise to the next defines the length of the day. Since day and night are in the long run of approximately equal length, it was natural that each should be divided further into hours, the number of which was set at 12 of daylight and 12 of darkness at or near the equator, where day and night are approximately equal, and where the problem first presented itself to the human mind. The subdivision of each hour into 60 parts, minutes, and each minute into 60 seconds is a device handed down to us from ancient Babylonia.

Next in importance to the sun as a measure of time is the moon. Its recurrent cycles give us the months, each cycle covering about 29½ days. Twelve such cycles aggregate 354 days or some 11 days short of a solar year.

Since the solar year does not correspond exactly with any definite number of lunar cycles, it is impossible to combine lunar months into a solar year with exactness. The nearest approximation is obviously a 12-month year, although it includes only 354 days. Different peoples in their calendars have used months of arbitrary length ranging in duration from 20 to 31 days.

The Maya of Central America used a

20-day month, although they were aware that this did not correspond with a true lunar cycle. Their solar year contained 18 such 20-day months, aggregating 360 days, a closer approach to the true number of days in a solar year than is given by 12 true lunar months. The Maya added 5 extra days to their 18-month year to make a solar year of 365 days. These extra 5 days however were not deducted from the ensuing month, so that the succession of months went on independently of the seasons and no attempt was made to have them come out in harmony. Spring began in whatever month happened to be current, its arrival being determined by the alignment of the sun with certain carefully placed stones.

Our present calendar came down to us from the Romans who in turn had it from the Greeks and Egyptians in large part. As revised by Julius Caesar at the beginning of the Christian era, the Julian calendar consisted of 12 months of varying length. The mean length of the solar year was recognized on astronomical evidence as being $365\frac{1}{4}$ days. Ordinary years were accordingly made to contain 365 days and an extra day was added in the shortest month, February, every fourth year. The month of July was so named in honor of Julius and it contained 31 days. February was assigned 29 days in ordinary years and 30 in leap-years. But Augustus the successor of Julius renamed the month succeeding July, August in his own honor and in order to give it equal importance with July in the calendar lengthened it to 31 days. So it was necessary to borrow a day from the shortest month, February, which thereafter had 28 days in ordinary years and 29 in leap-years, as it still does.

Thus was arranged the so-called Julian calendar which persisted unchanged for more than 1500 years, and except for a single modification still persists with us.

In estimating the length of the solar year as $365\frac{1}{4}$ days, Julius had made it too long by 11 minutes and 14 seconds, as more exact astronomical observations have shown, and in 128 years the error would amount to an entire day. The erroneous days continued to pile up century after century until in 1582 the matter was taken in hand by Pope Gregory XIII. He ordered the extra days to be cut out, ten of them, bringing the beginning of the year back to where it was at the beginning of the Christian era. To provide against a renewed over-correction of the calendar by leap years, Gregory directed that leap year should be omitted in all centenary years except those which are multiples of 400. Thus the year 1900, though divisible by 4 was not a leap year, but 2000 will be because it is a multiple of 400. Such is the present status of our calendar.

According to modern astronomy, however, a slight over-correction by leap years still persists in the Gregorian calendar. To eliminate this it has been proposed to make the year 4000 and all its multiples common (not leap) years. With this modification the beginning of the year will not vary from its present place in 200 centuries (20,000 years), which is good enough! The leap year rule, as thus qualified, would run as follows: Every year the number of which is divisible by 4 is a leap year, excepting the last year of each century which is a leap year only when the number of the century is divisible by four; but 4000 and its multiples 8000, 12000, 16000, etc., are by a further exception common years.

Pope Gregory's reform of the calendar in 1582 was promptly accepted by all Roman Catholic countries, but in the 16th century religious prejudices were very strong. Protestant England refused to take orders from Rome either on the calendar or on any other subject and thus a desirable reform was delayed

in all English-speaking countries for two centuries. The Eastern or Greek Catholic church was even more obdurate and still adheres to the Julian calendar. The Julian calendar was in use in the North American colonies, as in all other parts of the British Empire, until shortly before the American Revolution. Thus George Washington was born on Feb. 11, 1731, of the Julian calendar and he himself always regarded Feb. 11 as his birthday. But the error in the Julian calendar amounted to eleven days when Great Britain switched to the Gregorian calendar and so Washington's birthday became February 22 of the current calendar.

A complication in the measurement of time and in calendar making, which we have not yet considered, is introduced by the seven-day week. This arises not from astronomical but from social and religious considerations. Occasional days of rest and recreation are essential in a well-ordered society. In various parts of Africa, weeks of four, five, six and eight days are observed by the natives, usually in connection with a recurrent market day. The seven-day week originated in western Asia and spread to Europe and North Africa with the spread of the Jewish, the Christian and the Mohammedan religions, which agree in having a seven-day week though with a different holy or rest day in each.

Neither the 365-day year nor the month of 29 or 30 days is exactly divisible into seven-day weeks, so that in our present calendar each successive New Year's day falls on a different day of the week. Every other event which falls on a particular day of the month falls on a different week day in each successive year. This is only one defect but a serious one of our present calendar, and it is capable of eradication in a very simple way, as we shall see.

A second defect of our calendar arises from the varying numbers of days in the month. In the shortest month, February, it is 28 or in leap years 29. In certain other months the number is 30 and in the rest 31. One has to go through the lines "30 days hath September" etc., before he can feel sure how many days there are in the current month. Even then he can not tell without a calendar of the year before him how many Sundays, how many full weeks and how many week days there are in the month, since these change from year to year. All these items are of importance to the business man, the schools, the churches, the banks, and all of us. There should be no uncertainty concerning them and there need be none under a slight modification of the calendar, which would make every day in every year the same as regards the day of the week and the day of the month. To bring about this desirable uniformity, two different but related plans have been proposed. They are known as the 13-month calendar (a proposal now withdrawn) and the World calendar. The 13-month calendar would make every month of exactly the same length (four seven-day weeks) so that it would begin on a Sunday and end on a Saturday. The number of work days in each month would then be the same, except for the occurrence of special holidays. The standard year would thus consist of 52 seven-day weeks, would always begin on Sunday and would end on an extra Saturday as a 365th day. Another extra day would be added in leap years. But with these desirable features is included one serious disadvantage. The year is not divisible into equal half years or quarters, since thirteen is an odd number of months.

This difficulty is avoided and most of the advantages of the 13-month arrangement are retained in the proposed World Calendar. This retains the familiar 12-month year, and divides it into four quarters of equal length. Each quarter

begins on Sunday and ends on Saturday. It contains 3 months including 91 days, in its 13 weeks. Month dates always fall on the same week day from year to year. Each month has 26 week days plus Sundays, a uniformity very advantageous to business.

The first month of each quarter begins on Sunday and so contains five Sundays.

PROPOSED WORLD CALENDAR

FIRST QUARTER

	S	M	T	W	T	F	S
JAN.	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31				
FEB.				1	2	3	4
	5	6	7	8	9	10	11
	12	13	14	15	16	17	18
	19	20	21	22	23	24	25
	26	27	28	29	30		
MAR.						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28	29	30

Fig. 1

The other two months of the quarter contain four Sundays each. Each quarter thus includes 13 Sundays.

The first month of each quarter consists of 31 days (including the extra Sunday). Each of the other two months of the quarter consists of 30 days. The three months of each quarter are thus alike in length except for the extra Sunday of the initial month.

Each quarter includes 91 days, and combined the four include 364 days. An extra Saturday, a holiday called Year-day follows Dec. 30th and this makes the 365th day of the standard year, as in the 13-month calendar.

In leap years an extra Saturday, Leap-year day, a holiday, follows June 30th in the middle of the year, making a 366th day.

A world calendar thus revised would be "balanced in structure, perpetual in form and harmonious in arrangement." Only one group of business men is likely to object to it, those who print calendars, for their business will be greatly reduced. Each year's calendar will be the same, except for the extra Saturday in the middle of each leap year. Educators, scientists, and professional men would welcome the adoption of the world calendar which would greatly simplify the arrangement of schedules and appointments.

Holidays such as Easter could be stabilized and given a fixed place in the calendar, preferably at the week end so as to make 2-day or 3-day periods of recreation possible without breaking into the working week. Easter of course comes on Sunday, Christmas would come regularly on Monday, Washington's birthday could be moved to the day which he celebrated, the 11th of February, Lincoln's birthday would come on the following day, Sunday February 12, or if celebrated on Monday, the 13th a single national 3-day week-end holiday in mid-February would result. Labor day naturally falls on Monday, Sept. 4, national election day could be fixed on Monday, November 6. Armistice day might well be celebrated, as in England, simply by a 2-minute pause on Saturday, November 11th, and Thanksgiving day could be stabilized on Thursday, the 16th of November, or preferably advanced to the 18th, Saturday, or the 20th, Monday.

The 17th of March, St. Patrick's day to Irish Americans, and Evacuation day

to all Bostonians, since Washington forced the British soldiers out of Boston on that date, would fall on Sunday and its celebration probably on Monday. Only the 4th of July (Wednesday) and Columbus day (Thursday) would remain as mid-week holidays widely celebrated in the U. S.

By way of summary, we may note that the chief source of the imperfections of our present calendar lies in the attempt to use simultaneously three different methods of measuring time (1) the solar year of 365 days, (2) the lunar month of 30 days more or less, and (3) the conventional 7-day week. No two of these come out in agreement.

We can not get away from a solar year of slightly more than 365 days, since on this the recurrence of the seasons depends. Our problem then is to bring into conformity as nearly as possible with the solar year both the months and the weeks. Our present calendar does neither of these things adequately. To make up a year of twelve months we have to adopt months differing in length by as much as three days, which is poor time engineering. To make up a year of 365 days we have 52 seven-day weeks, with one day left over. By beginning the next week on this left-over day, each successive year begins on a different week day. We are confronted with the same difficulty as regards the day of the week, as confronted the Maya regarding the months in relation to the year. Instead of skipping the five extra days at the end of a year, and beginning a new year with a new month, they made the five extra days part of a new month and thus there was no correlation between a particular month and a particular part of the year. And we, instead of skipping the left-over day at the end of the year and beginning the new year with a new week, keep the succession of seven-day weeks uninterrupted regardless of what it does to our yearly calendar.

The difficulty concerning the lack of agreement between days of the month and days of the week in successive years is met in both the proposed 13-month calendar and the proposed World calendar in the same sensible way. The extra day at the end of the year is not put into a seven-day week, but is made a special holiday, a year day or extra Saturday, as you choose to call it. The extra day of leap years is treated in a similar way, as leap year day which does not make part of a seven-day week.

The variation in length of the months in our present calendar is obviated in a different way in the 13-month calendar and the World calendar. In the former each month would consist of exactly four weeks, 28 days, the total being 364 days, with year day not a week day, making the 365th. The impossibility of having quarter years made up of like numbers of months is the chief defect of this proposed calendar.

In the World calendar, there would be four equal quarter years of 91 days each, with one extra year day making the 365th.

Every month would contain the same number of week days (26) and the same number of Sundays (4) except the first month of each quarter which would contain a fifth Sunday, the odd or 91st day of the quarter.

How and when could we change from the present to the proposed World calendar with the least amount of disturbance to existing conditions? January 1, 1945 would be a practicable date, since that would be the same day of the week, Sunday in both calendars.

Of course no country single handed could bring about the change. It will have to be by joint action of a large part of the civilized world. Already 14 nations have officially approved the World Calendar. In response to a proposal made by Chile and sent to all governments by the Council of the League of Nations in 1937, favorable

replies were made by six American governments, *viz.*, Brazil, Chile, Peru, Uruguay, Mexico, and Panama; as well as by Esthonia, Greece, Hungary, Norway, Spain, Turkey, Afghanistan and China. If the United States and Canada were to join with Mexico and the South American Republics in adopting the World Calendar, it seems highly probable that the rest of the world would soon accept it. There is no religious opposition in sight today as there was when Pope Gregory instituted his reforms, nor is there ground for political opposition. Nothing but the inertia of custom holds back a reform which would benefit all classes of people, not least of all students and teachers.

MYSTICISM IN SCIENCE

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TENSE and expectant, the audience watches. Quickly the magician opens the lid of the narrow vertical box which has just closed so suddenly upon his startled assistant. There hasn't been time to arrange a trick, and he seems frightened. Something must be wrong. It is. The girl is gone—vanished. No—there she comes out of a far door, no longer in a strait-jacket, but pert and free in shorts and spangles.

The tension relaxes.

"I'm sorry," explains the magician. "I didn't mean to say 'hocus pokus' quite so fast."

The crowd laughs. It is superior now. Everybody knows that the stock magic phrase had nothing whatever to do with the unaccountable disappearance of the girl.

But suppose the trappings of the act had been altered a little. Suppose the chief actor had worn an exotic head-covering and had called himself a Brahman seer. Suppose he had explained gravely that it is possible, by the new vibratory technique, to waft his subject temporarily into the fourth dimension. In that case it is likely that he would have gained a credulous convert or two. Of course nobody would know for sure what he had really meant, least of all the seer, but the intriguing name of the obviously effective cause, the redoubtable fourth dimension—fairly reeking as it is with intellectual content—would be very, very impressive indeed. The prestige of science, striking obliquely here, would help the subtle explanation to get a respectful hearing. Mysticism and science, combined, make a well-nigh irresistible team.

For mystery has a glamor of its own. Consider the very number of synonyms for "mysterious" in my small and abridged dictionary: "abstruse, cabalistic, dark, enigmatical, hidden, incomprehensible, inexplicable, inscrutable, mystic, mystical, obscure, occult, recondite, secret, transcendental, unfathomable, unfathomed, unknown." There, in the staid dictionary, you have a glimpse of the thought patterns of humanity, of the almost tangible awe which clings like a persistent cloud about that which is not understood. In a page of brief definitions this sudden deluge of words clearly shows where fascination lies. The human race is mystic to its very core.

But obviously an idea so many-faced as "mysticism"—so broadly tangled with the hopes, fears and confused thinking of mankind, can not go into the premise of a logical train of thought unless we compress it somehow into an understandable unity. For the purposes

of our discussion we must chop the word clear of its subtle fringes of meaning. Two major ideas will remain, the first one signifying utter sham, as pompous and pretentious as it is amusing; while the second connotation—the one which remains respectable under scrutiny—is the mysticism which lies at the heart of modern science. We shall come to that later.

But first of all let it be understood that we are not here concerned with the simple, folksy brand of mysticism which would connect a case of measles with the path-crossing activities of the neighbor's black cat. Superstition can naturally have little to do with science, which, again according to my dictionary, means "knowledge verified by exact observation, and thinking which harmonizes with that knowledge." For obviously it is not exact observation and exact thinking which has established the dubious connection between a pinch of salt thrown over the left shoulder and a subsequent windfall on bank night, or between not sitting on a handkerchief and a run of flat hands at the bridge table.

No, the mysticism of which we write is so far from crude and naive superstition that it has actually an intellectual front, an air about it, so to speak. It is nurtured by scientific phrases and a specious imitation of learning. It has a subtle, seductive quality which inevitably traps the would-be sophisticates who fawn before impressive but indigestible ideas. It is astrology, it is the fourth dimension; it is curved space, it is nonexistent or misunderstood profundity. It is the invoking of a cause for a given result which merely makes that result somewhat more incomprehensible than before, like the above use of the "fourth dimension" to account for the magician's vanishing trick. It is muddle-headedness disguised as insight. It is fraud, though in its subtler phases it fools us all now and then.

Take astrology, for instance, which accounts for the rundown condition of John A. Fitz as being due to a bad combination of the planets. This explanation is not satisfactory to the astronomer, who studies the celestial bodies themselves instead of their effects upon the human disposition; who misses, somehow, the direct connection between Mars and the human midriff; and who also misses, sometimes quite terribly, the cash that he might collect from eager and opulent customers who want to know all about the planet Saturn and its thrilling evil influence. But the explanation, nevertheless, may sound convincing enough to John A. Fitz himself, who, even though moderately well informed and equipped for everyday living, does not, unfortunately, know enough about the planet Jupiter to absolve it of all blame for the past affairs of his wife. Here (thinks John) is a fellow who knows first hand about the stars and their effects upon people, and who is John A. Fitz to question the findings of the savants? After all, science is a wonderful thing. Better be safe than sorry; better pay the man for the horoscope. Thus one more victim of scientific mysticism pays his tribute to muddled thinking.

And yet the really adult members of society will not, for the most part, be fooled by this particular brand of mysticism. While it is conceivable that a clerk in the Outer Offices of the Grand Planner may keep a careful record of astrological predictions, and may do his level best to bring to pass those which do not contradict each other, it nevertheless seems evident that this delightful theory needs some fairly substantial support from unbiased records. And one of the more or less patent facts of general knowledge is that history is strangely lacking in accounts of a mammoth statistical campaign, involving the dispositions and destinies of millions of human beings, during which the star prophets

got their data. Without such data their conclusions would be worthless even if they were not absurd to begin with in the light of astronomical facts. The intelligent man in the street may not know about the absurdity; but he is likely to sense the dubious nature of the evidence when he learns, sooner or later, that astrology and astronomy are not really the same, and that it is only the astronomers who have access to the large telescopes of the world. Thus he learns that the bolstering statistics which the astrologers lack are not even now being gathered for them. And thus, if he has reasonably good judgment, he decides to worry along without his horoscope.

This being the case, we can dismiss rather lightly the mysticism of the sky-charlatan. He could never, never deceive the intelligentsia to whom this essay is directed. And incidentally, we can explain with airy ease the widespread vogue of astrology to-day. The explanation lies chiefly in the bread-and-butter urge of numerous national newspapers and magazines to share in the golden harvest reaped from the bamboozling of the more lightheaded public, together, of course, with the generous supply of lightheadedness itself. Surely it is astrology which gives the final and clinching demonstration of Puck's pungent phrase: "What fools these mortals be!"

But what of the girl who was wafted into the fourth dimension? Isn't this a deeper problem? Since reputable mathematicians often speak quite learnedly and seriously of this thing called "four-space," why can't it be possible that physical objects now and then slip out of the ordinary three-dimensional framework which seems to represent reality to our limited faculties, and that they become therefore invisible, though really right at hand in the fourth dimension? Sounds plausible, doesn't it? Well, there we have a perfect example of the illegitimate type of scientific mysticism, of the impressive-sounding explanation which leaves the explainee two thirds addled, half convinced and wholly in the dark. The loophole for sanity, as is often the case, lies in recognizing the prostitution of words. When the mathematician talks of four, five and n dimensions he is simply speaking of four, five and *n independent variables*. The three dimensions of a room, described roughly as length, width and thickness, or up-and-down, right-and-left and backward-and-forward, represent the first simple space concept associated with the word "dimension"; and the desertion of this concept for a new meaning applied to the old word is the cause of the whole sorry confusion. It is this change of meaning which allows us to speak of *time* as a dimension; and it is still true that, outside of useless and metaphysical speculation, there are three and only three dimensions of *space*. The fourth dimension of mystic significance is as nonsensical as the fourth corner of a tin triangle.

Not that the mathematicians themselves are blameless. Just as they talk unfairly about "dimensions" with secret reservations in their hearts, so also they prate of "four-space," "five-space" and, of course and inevitably, their beloved "n-space," where as many variables as they please can shoot out along n mutually perpendicular lines. Actually they know what they are talking about (we hope), but again they have swindled the public. And sometimes we fear that, in their enthusiasm and forgetfulness, they may possibly have swindled themselves.

It all comes about because in "analytic geometry" they have invented a beautiful way to illustrate the equations of algebra with the points, lines, curves and surfaces of geometry. This works wonderfully on a plane, where the relative sizes of two varying quantities can be

illustrated with lines and curves. It still works in actual space with its three dimensions, in which the illustrating figures can be neatly approximated by means of strings and paper surfaces. But when four or more variables are used, this picturing device flatly and utterly fails. Yet the investigator finds that he can continue to make algebraic discoveries by using algebraic devices which were suggested by the geometric pictures in the cases where those pictures applied. Then what does he do? To help his thinking, and heedless of the fraud he is perpetrating, he denies that he has gone out of geometry, and he begins to talk mystically of such things as "hyper-spheres" whose intersections with planes are spheres. Neither he nor any one else can draw pictures of such monstrosities. Intoxicated with his verbiage, he begins to see Alice-in-Wonderland "four-space" on the horizon; and soon he putters around in "*n*-space" as casually as a child with a pile of blocks. And by this time he may actually have forgotten that his picturing device ever did break down, and that he is not still using a mystic sort of geometry in his thinking.

Please do not misunderstand me. I cast no aspersions on the beauty and usefulness of the mathematical results thus obtained. My objection is solely to the terminology which implies that old-fashioned "three-space" is a simpleton's illusion and an artificial shackle. Einstein himself gets along with it, in spite of the impression to the contrary. He merely points out that a fourth variable, time, is needed to locate an event as contrasted with an object. Rightly understood, there is no mystery here, no realm of the ultra-ultra accessible only to the mathematician in a trance. With no intention here of losing the reader in the Einstein Theory, we wish merely to point out that it would be a much more difficult undertaking to lose him physically in the mathematician's "four-space."

Mysticism in science, then, as we have been describing it, is either pretentious fraud, such as astrology, based upon borrowed prestige, or else it is a straining for weird and meaningless conclusions which spring from the accidental implications of unfortunate technical terms. Yet beyond the sham lies the reality of patient, respectable scientific thought to-day—and what do we find there? Why, a new sort of mysticism—a legitimate sort. We may describe it roughly as attempted explanation which awes and baffles because the universe itself happens to be awesome and baffling; and which apparently violates all common sense simply because the so-called "common sense" is not infallible. Mathematicians run squarely into this mysticism of things-as-they-are in grappling with the idea of infinity; astronomers meet it in the problem of the nature and bounds of space; and modern physics is shot with it from end to end.

By way of example, the algebra teacher's mild assertion that there is no smallest fraction bigger than zero often brings a protest from the student's outraged "common sense," though it is not hard, in this case, to still the uproar. But in the simple explanation, lighted as it is with imagination if it be explanation at all, a startling new idea must appear. As adults let us examine this idea.

Imagine a point, on the wall of a large room, which is nine tenths of the way from end A to end B. Then magnify the remaining one tenth so that it looks as long as the whole room now does, and take a second point nine tenths of the way to B again. Repeat the process over and over, each time magnifying the remaining tenth until it covers the whole original wall. Soon we transcend the world of measurement and reach a realm in which the physicist's atom has swelled to the vastness of the astronomer's uni-

verse. And yet the process continues—there is nothing in nature or logic to stop it. Inward and inward we march, to realms as real, perhaps, as those where man is dominant, and yet as far outside his instrumental reach as the blankness beyond the galaxies. Here lies the universe of the minute, as staggering, endless and full of potentialities as the great outside itself. Surely here is mysticism —legitimate mysticism—inherent in the nature of things and glimpsed through the magic keyhole of mathematics.

Illustrations swarm before us. Though the conclusions of "non-Euclidean geometry" are flawless mathematical deductions, they might well be considered unimportant because their intuitively preposterous premises rub the common-sense raw; yet some of these theorems seem to fit the startling universe of Einstein. The Einstein theory itself crashes through the structure of nineteenth century science founded by geniuses like Newton; but its conclusions are not to be brushed aside lightly because they flout this authority, nor because on first thought they look so highly unreasonable. The theory is intellectually respectable; make no mistake about that. But even here, in the popular explanations, at least, there is a taint of the more reprehensible type of scientific mysticism, of impressiveness gained through a confusion of terms, of statements which are false in the sense that they do not mean what they seem to mean. But all in all, when we examine the theory fairly we find, perhaps, that we have to go along with it, at least part way, while it tampers with time and space, does away with gravitation, and wipes out the ether through which light was said to travel. It is a highly bothersome complication of the old simple set-up; but nature seems to join Mr. Einstein in demanding that we give it heed.

Thus, in this modern age, mysticism once more raises its head. Snatched out of the murk of superstition by deeper and more accurate thinking, it turns calmly on its rescuer and lo, that saving science itself goes mystic. For it can not escape the universe around it—a universe of living things which sprang somehow from unfathomed beginnings; of forces, such as magnetism and gravitation and electricity, which can be labeled but not really known; of uncanny processes by which the potent magic of thought, stemming strangely from the sodden gray mass of the brain, creates new forms, starts new sequences, sweeps inward to the atom and outward to the galaxies of space. This it sees, and this it reckons with. Never again, perhaps, will chastened science expound the facts of the case with the smugness of old. Like the veriest bumpkin, it now senses the mystery inherent in the nature of things; with the humblest of men it tastes the brew made of wonder, bafflement and awe-struck recognition of all that is yet unexplained.

HUXLEY'S "EVIL" INFLUENCE

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TEN years ago self-appointed critics of Thomas Henry Huxley expressed the opinion that "the evil that a man of Huxley's calibre left to live after him will never be measured."[1] After reading such an estimate the author undertook to "measure" Huxley's "evil" influence on his many friends and enemies. The results of his research are embodied in the present paper.

In order to show the influence which Huxley exercised among his students, a few representative tributes will be quoted. However, it is to be noted that most of these represent the opinions of students whom he encouraged to continue in some branch of science and who later became known in their field. The tributes of that great body of unknown students have never been heard, but we may well believe that the sentiments which they would express would sound no discord with the major chord which we shall strike.

That it was not the laboratory system alone that made Huxley a great teacher is shown by the appreciative words of Professor W. J. Solas, who was his student before the advent of the laboratory teaching:

> It was never my privilege to know Huxley as a friend; he was my teacher, that was all; with reverence and affection I worshipped from afar. Now as I look back over a long life, I feel, while recognizing how great is my debt to my many distinguished teachers, that I owe to him more, both morally and intellectually, than to any other I can name.[2]

Henry Fairfield Osborn also seems to have been influenced more by Huxley's lectures than by his laboratory system, since, as he tells us, Huxley came through the laboratory not more than once a week. "Breadth and depth, culture from every source, lack of dogmatism, faith in the educational value of science without prejudice to the classics, these," Osborn felt, "were the keynotes of Huxley's influence as a teacher and writer."[3] In appreciation of this influence he dedicated his work on "The Age of Mammals" "to the memory of Balfour[4] and of Huxley, my chief teacher in comparative anatomy."[5] While at Columbia University Osborn used his "old master, Huxley" as a center for some remarks concerning a liberal education.[6]

Professor S. H. Vines, who introduced the Huxleyan system to Cambridge, received his training both as a student and demonstrator under Huxley. And according to his own testimony, "it was altogether a memorable experience, an invaluable apprenticeship in the art of teaching science."[7] Another of Huxley's demonstrators, T. Jeffery Parker, could not decide "whether a professor is usually a hero to his demonstrator," but he did know that he had "never ceased to be impressed with the manliness and sincerity of his character, his complete honesty of purpose, his high moral standard, his scorn of everything mean or shifty, his firm determination to

[1] J. H. Massingham and Hugh Massingham, ed., "The Great Victorians," pp. 227–238. New York: Doubleday, Doran and Company, Inc., 1932.

[2] W. J. Solas, *Nature*, 115: 748, May 9, 1925.

[3] Henry Fairfield Osborn, *Nature*, 115: 726, May 9, 1925.

[4] *Cf.* p. 4.

[5] Henry Fairfield Osborn, "Impressions of Great Naturalists," p. 71. New York: Charles Scribner's Sons, 1924.

[6] Henry Fairfield Osborn, "Huxley and Education," New York: Charles Scribner's Sons, 1910.

[7] S. H. Vines, *Nature*, 115: 715, May 9, 1925.

speak what he held to be truth at whatever cost of popularity."[8]

In addition to those previously mentioned, many other representative biologists were directly trained by Huxley. Among these we may mention Saville Kent, C. Lloyd Morgan, George B. Howes, W. Newton Parker,[9] Patrick Geddes, Angelo Heilprin and Angelo Andres.[10] These serve to show Huxley's ability not only to single men out but also to inspire them to investigate the problems which were pressing for solution. Moreover, since the majority of them became professors of biology, they have spread Huxley's influence as a teacher over the globe. One of them, Professor Howes, continued Huxley's work as professor of biology in the Royal College of Science.

It is a curious coincidence that men who frankly and freely express their indebtedness to Huxley became professors in the biological sciences at both of the old English universities. This fact, as well as the offer to Huxley himself of the Linacre professorship of physiology at Oxford on the death of Professor Rolleston,[11] well illustrates the change which had come over the universities even in Huxley's lifetime. Both Michael Foster and E. Ray Lankester were demonstrators for Huxley during the introduction of the laboratory system at South Kensington. Foster later went to Cambridge and Lankester to Oxford.

During the first Huxley lecture at the Charing Cross Hospital Medical School, the school where Huxley received his medical training, Sir Michael Foster said:

> If I venture to say that the little which he who is now speaking to you has been able to do is chiefly the result of Huxley's influence and help, it is because that only illustrates what he was doing at many times and in many ways.... His indirect influence was perhaps greater even than his direct.[12]

Huxley always felt that he had discovered Foster, and it was Foster who discovered Francis Balfour,[13] the young investigator whom we have already mentioned in connection with the joint dedication of Osborn's work on "The Age of Mammals." At the time of Balfour's tragic and untimely death in the year in which Darwin died, Huxley wrote:

> Heavy blows have fallen upon me this year in losing Darwin and Balfour, the best of the old and the best of the young. I am beginning to feel older than my age myself, and if Balfour had lived I should have cleared out of the way as soon as possible, feeling that the future of Zoological Science in this country was very safe in his hands.[14]

It was the elder Lankester who extended the original Huxleyan plan of beginning with the simple forms in biology and progressing to the more complex types. His son, E. Ray Lankester, spread the system to Oxford. He tells us that ever since he was a little boy Huxley had been his "ideal and hero." After Huxley's death he wrote:

> There has been no woman or man whom I have met on my journey through life, whom I have loved and regarded as I have him, and I feel that the world has shrunk and become a poor thing, now that his splendid spirit and delightful presence are gone from it.[15]

Even those from whom Huxley was at times estranged because of a fundamental difference in view-point are able to express appreciation for his teaching. St. George Mivart, the biologist, who accepted the Roman Catholic faith and,

[8] Quoted from the reprint of Parker's Recollections to be found in Leonard Huxley, "Life and Letters of Thomas Henry Huxley," Vol. II, pp. 447–448. New York: D. Appleton and Company, 1901.

[9] For the first four names, *cf.* Henry Fairfield Osborn, "Impressions of Great Naturalists," p. 70. New York: Charles Scribner's Sons, 1924.

[10] For the last three names, *cf.* Patrick Geddes, *Nature*, 115: 740–743, May 9, 1925.

[11] *Cf.* Leonard Huxley, *op. cit.*, Vol. II, p. 32.

[12] Michael Foster, "Recent Advances in Science, and Their Bearings on Medicine and Surgery," *Smithsonian Report*, p. 363, 1896.

[13] Leonard Huxley, *op. cit.*, Vol. II, p. 420.

[14] *Ibid.*, p. 41.

[15] *Ibid.*, p. 447.

after trying to reconcile evolution with it by a theory of derivative creation, was finally excommunicated, says of Huxley:

> It is almost needless to say that his teaching, both its manner and method, made a profound impression on me.[16]

Mivart had studied biology before he came to Huxley. He was therefore permitted to attend lectures as "an honorary student." However, in his Reminiscences he writes:

> As to science, I learnt more from him in two years than I had acquired in my previous decade of biological study.[17]

So he later sent his son to Huxley that he too might profit by such instruction.

Thus far, we have drawn our tributes largely from those who were primarily interested in biology. But Huxley's influence is attested also by students whose major interests were not in the field of science. As a representative of this class we may quote the impression which Reverend E. F. Russell, curate of a London parish, gives of Huxley:

> When, like Marcus Aurelius, in the evening of my life I look back upon past years and count up the names and benefactions of those to whom I owe so much, I find myself dwelling with especial gratitude upon the name of Thomas Henry Huxley, what he was and what he did; for from him I learned, so far as I was capable of learning, not only the principles of biology, and of the scientific method, but also, from his example, such high qualities as the habit of observation, accurate and intense, of patience and thoroughness in all we undertook, and—I would add—of courtesy to strangers.[18]

The foregoing list of students and laboratory associates is not intended to be exhaustive but only representative. It is impossible to give even a brief word of appreciation from all of Huxley's students who have expressed them. Moreover, we must ignore possible influences on such men as F. O. Bower and D. H. Scott, Marshall Ward and Alexander mac Nab, Burdon-Sanderson and H. Newell Martin.[19] However, since Huxley's influence was exerted not only through his students and those who assisted him in their guidance, but also through his many friends and correspondents, this paper would be incomplete without a word concerning the closest of these.

Huxley's friends and correspondents included some of the greatest thinkers of the nineteenth century. With some of these he formed life-long friendships in which the influence was reciprocal. The influence of Charles Darwin on him is too well known to require further comment, but it is not unlikely that Huxley also exerted an influence on Darwin. That Darwin valued his opinion is shown by the fact that Huxley was one of three judges, Sir Charles Lyell and Sir Joseph Hooker being the other two, upon whose decision as to the merits of the "Origin of Species" he determined to abide.[20] After his favorable verdict, Huxley became the "general agent" and "bull dog" for Darwin, and was easily the most aggressive of the judicial trio in imparting the essentially creative thought of the book to the world. That Darwin valued the generalship of Huxley is shown in an appreciative letter which he wrote to him before the tide had turned:

> The pendulum is now swinging against our side, but I feel positive it will soon swing the other way; and no mortal man will do half as much as you in giving it a start in the right direction, as you did at the first commencement.[21]

The pendulum did "swing the other way," as almost any schoolboy is now aware. That it did is due not only to Darwin and Huxley, but also to Sir Joseph Hooker, Alfred Russell Wallace and Herbert Spencer. Of this latter

[16] St. George Mivart, *The Nineteenth Century*, 42: 988, December, 1897.

[17] *Ibid.*, p. 991.

[18] E. F. Russell, *Nature*, 115: 752, May 9, 1925.

[19] These men served either as students or assistants under Huxley at different times. *Cf.* F. O. Bower, *Nature*, 115: 712–714, May 9, 1925.

[20] Francis Darwin, "The Life and Letters of Charles Darwin." Vol. I, pp. 529–530. New York: D. Appleton and Company, 1911.

[21] Francis Darwin, *op. cit.*, Vol. II, p. 328.

trio, Hooker was probably closest to Huxley. For over forty years these two friends worked together with never a misunderstanding. Time after time each sought and gave advice. Almost a hundred letters from Huxley to Hooker have been collected by the former's son.[22] That Hooker was not influenced would be inconceivable. If space permitted many evidences of this influence could be cited, but we must content ourselves with just one instance. Even after his first interview with Huxley, Hooker felt that with reference to the Salpae, a much misunderstood group of marine Hydrozoa, Huxley's "observations on their life-history, habits and affinities were on almost all points a revelation"[23] to him.

Although Huxley and Wallace met only on rare occasions and corresponded even less frequently, Wallace sums up a lifelong impression of Huxley in one sentence which we shall quote as representative of his feeling:

> I owe him thanks for much kindness and for assistance always cordially given, and although we had many differences of opinion, I never received from him a harsh or unkind word.[24]

While Spencer quarreled with Huxley, as indeed he did with many of his friends at one time or another,[25] he regarded their friendship as "an important factor" in his life.[26] The proofs of the "First Principles" were submitted to Huxley for his criticism.[27] Spencer felt that Huxley was "too yielding" in the sense that "if he is asked to undertake anything, either for the benefit of an individual or with a view to public benefit, he has difficulty in saying no."[28] But Spencer concludes that he should not "comment on this undue yieldingness and undue devotion to work which follows it" because he often betrayed Huxley into them by seeking his criticisms.[29]

However, Spencer probably relied more on the judgment of John Tyndall than he did on Huxley's criticisms. The final drafts of most of his writings seem to have been submitted to Tyndall for his approval.[30] For forty years the emotional Irishman and the reserved Englishman indulged in their intellectual companionship from afar. And this absence of frequent personal contact probably explains the length of the friendship. But the friendship of Tyndall and Huxley was even of longer duration than that of Tyndall and Spencer, since indeed it was Huxley who introduced Tyndall to Spencer.[31] Moreover, it was more of an intimate companionship than that of Spencer with Tyndall. Although Huxley could not claim Tyndall's birthyear as his own, as Spencer could, the two had many things in common. They were almost as brothers, and were often confused in the popular mind. Thus, although Huxley had been married for over twenty years in the year of his visit to America, the newspapers reported him as on his honeymoon with a titled bride. The fact was that Tyndall had married the daughter of an English Lord in this same year. Some years later Huxley wrote to Tyndall, informing him that he had "given up the struggle against the popular belief that you and I constitute a firm."[32] Throughout their lives the English biologist and the Irish physicist worked together for the recognition of science.

22 These are chronologically indexed in Leonard Huxley, *op. cit.*, Vol. II, pp. 518–520.

23 Leonard Huxley, *op. cit.*, Vol. I, p. 232.

24 Leonard Huxley, *op. cit.*, Vol. II, p. 432.

25 Maynard Shipley, *Open Court*, 34: 252, April, 1920.

26 Herbert Spencer, "An Autobiography," Vol. I, p. 466. New York: D. Appleton and Company, 1904.

27 Herbert Spencer, *op. cit.*, Vol. II, pp. 553–556.

28 Herbert Spencer, *op. cit.*, Vol. I, pp. 467–468.

29 *Ibid.*, p. 468.

30 Maynard Shipley, *op. cit.*, p. 253.

31 Herbert Spencer, *op. cit.*, Vol. I, p. 485.

32 Leonard Huxley, *op. cit.*, Vol. II, p. 274.

In 1864 Huxley felt that he and his friends were gradually drifting apart because of the stress of circumstances, so he proposed to Hooker that some kind of a regular meeting be established. Whereupon eight friends resolved to dine together once each month. These included an old quartet whom we have met: Huxley, the zoologist and later dean of the Royal College of Science; Hooker, the botanist and later director of Kew Gardens; Tyndall, the physicist and later superintendent of the Royal Institution; and Spencer, the philosopher and later the author of the "Synthetic Philosophy." The new quartet we must introduce: Edward Frankland, the chemist and later professor of chemistry at the Royal College of Science; George Busk, the anatomist and later president of the College of Surgeons; Thomas Hirst, the mathematician and later director of naval studies at the Royal Naval College, Greenwich; John Lubbock, the archeologist and later the author of "Prehistoric Times." At the second meeting of the club William Spottiswoode, "who carried on the business of the Queen's printer," became the ninth member of the group.[33] No more members were ever added because it was agreed that the name of any new member suggested must contain "all the consonants absent from the names of the old ones." Thus, "the lack of Slavonic friends . . . put an end to the possibility of increase."[34] For a name the group "accepted the happy suggestion of our mathematicians," says Huxley, "to call it the X club; and the proposal of some genius among us, that we should have no rules, save the unwritten law not to have any, was carried by acclamation."[35]

We have taken the time to give an outline of the X-Club not so much because of the influence of the club, although this was considerable, as to show the influence of Huxley on his friends. Such a group gave him a training quarter, so to speak, from which officers for the scientific cause would be drawn. As teachers their students would be taught to acquire "right ideas." This was the influence which Huxley indirectly exerted on a group, unique in the intellectual eminence of its members. All except Spencer were fellows of the Royal Society; three became presidents of the Royal Society; five received the Royal Medal; three were recipients of the Copley Medal; six were elected to the presidency of the British Association for the Advancement of Science. Once each month these eminent representatives of eight branches of science and its philosophy dined together; often they entertained eminent guests, including Darwin, Clifford, Strachey, Bain, Morley, Galton, Agassiz, Youmans, Gilman, Marsh and Helmholtz; during the summer week-end excursions of the X's and their yv's would widen the community of interests. For nineteen years these friends were able to enjoy their reciprocal influences before death broke the circle of friendship. And before nine more years had passed three of the links were missing and the chain so weakened that it was discarded.

However, Huxley's influence was exerted through other than scientific channels. He visited Benjamin Jowett, Master of Balliol, at least once each year. Dean Stanley and Charles Kingsley were two of his most sincere friends. His letters to the latter are some of the most revealing of his utterances. He even numbered the poets among his friends. Alfred Lord Tennyson, whom he met at various times at the Metaphysical Society, described him as "chivalrous, wide, and earnest, so that one could not but enjoy talking with him."[36]

[33] This enumeration is based upon that given in Leonard Huxley, *op. cit.*, Vol. I, pp. 277–278.

[34] Thomas Henry Huxley, *The Nineteenth Century*, 35: 10, January, 1894.

[35] *Loc. cit.*

[36] Hallam Tennyson, "Alfred Lord Tennyson," A Memoir, Vol. II, p. 110. New York: The Macmillan Company, 1898.

With all his friends, Huxley also had his enemies. Richard Owen he had dethroned from his position of authority in anatomy; the Lord delivered Samuel Wilberforce into his hands at Oxford; he had made short work of Gladstone's rhetoric. Huxley places this triumvirate in the same class, "a very curious type of humanity, with many excellent and even great qualities and one fatal defect —utter untrustworthiness."[37] But it was this defect against which Huxley's passion for truth revolted. No compromise was possible.

If Huxley had his enemies at home, he also had his friends abroad. In America President Daniel Coit Gilman valued his advice with respect to the incumbent for the first chair of biology at Johns Hopkins University. In Germany Ernst Haeckel built upon his foundations. In Italy Dohrn was an appreciative correspondent. As representative of this group of foreign friends, we shall quote the tribute which Haeckel's countryman, R. Virchow, paid when he delivered the second Huxley lecture at the Charing Cross Hospital Medical School. On this occasion Professor Virchow said:

> In truth, the lessons that I received from him in his laboratory—a very modest one according to present conditions—and the introduction to his work which I owe him form one of the pleasantest and most lasting recollections of my visit to Kensington.[38]

The many tributes to Huxley which we have quoted in the preceding paragraphs tend to show the influence which he exerted through his many students, associates, friends and correspondents. His practices were imitated, his lectures and writings were quoted, and his life became a lesson which others studied, an example which they tried to follow. In the face of the statement of our critics, it is important to note that the tributes stress Huxley's moral influence as often as they do his intellectual. Thus, Parker was impressed with his "high moral standard"; Solas expresses his debt as both moral and intellectual; and many of the other tributes imply traits which are recognized as essential to any system of morality. But the reader can judge for himself whether the lives of these influential men who have expressed so great a debt to Huxley or the empty rhetoric of critics shall constitute the greater evidence of Huxley's real influence.

[37] Leonard Huxley, *op. cit.*, Vol. II, p. 362.

[38] R. Virchow, "Recent Advances in Science, and Their Bearing on Medicine and Surgery." *Smithsonian Report*, pp. 571–572, 1898.

BOOKS ON SCIENCE FOR LAYMEN

MEDICAL RESEARCH[1]

SOMETHING may happen in the ectoderm when it folds in to make the human brain so that the individual possessing that brain has such an abnormal amount of curiosity and intellectual ability that he becomes what we know as a "researcher." This unique and not too widely distributed capacity lays out the paths along which nearly all our human advances are made. In the last fifty or sixty years, research ability in the field of medicine has taken advantage of the discoveries of physical and biological sciences and has gone ahead at a preposterous rate, compared with such progress in the past.

To study this type of research ability, to review the qualities of the medical research worker, to bring out the relationships between the universities, the foundations and medical research, is the object of these lectures delivered by Dr. Gregg on the Terry Foundation at Yale University. Dr. Gregg has a uniquely urbane and brisk style of writing. He fills his pages with apt quotations drawn from his wide reading and experience, but fundamentally his lectures have that particular quality which is known as "horse sense." It is this that makes his book of substantial value.

Dr. Gregg has had the chance to see new plants develop for medical schools, and with new buildings and new administrative responsibilities research by some of the best workers rapidly diminish. He has come in contact throughout the world with that peculiarly important atmosphere that is created by a research group. He, too, realizes the inevitable wastage of experimental research. Tests and experiments cost money, and often the results are nil or practically nil. In this expensive field of research the universities and the foundations have done much together. I think that Dr. Gregg's emphasis on the importance of fellowships is correct. In the long run, research is a wager on the capacity of men to grow and to continue their interest and enthusiasm in discovering new things. The foundations have gone a long way to establish the spirit of research and to support men who seemed likely to be most successful. At times they have seen their money go into dry holes; dust pockets are found in medical research as well as in oil fields.

The aim of the foundations to emphasize more local and university support as the foundations move to other fields is well brought out by Dr. Gregg. The weaning process is in many ways the most important element in developing research. To wean a research worker from foundation aid because he himself has become unproductive, or to pass him over to some other established institution because of his achievement, is necessary if medical research is constantly to go forward. Nuclei of research are thus spread over the country and the world. New men and new areas of interest must constantly be found. It is here that the foundations have their most significant opportunity. Fundamentally research depends upon surplus time and in a teaching institution upon overstaffing with men capable of research and enthusiastic for it.

Dr. Gregg's book is a real contribution to the furtherance not only of medical research but of all other forms of research as well.

RAY LYMAN WILBUR

[1] *The Furtherance of Medical Research.* Alan Gregg. ix + 129 pp. $2.00. 1941. Yale University Press.

INFORMATION FOR THE AIR NAVIGATOR[1]

THIS book is unique in that it combines in one volume all the subjects of vital importance to the navigator in the air—navigational astronomy, maps and weather. In fact, it was prepared at the request of the Army Air Corps Flying Training Command, in pursuance of a plan for training in mathematics and the physical sciences that extends from high school through college. The committee that outlined the course for the Army Air Corps was appointed by Dr. Forest R. Moulton, and the author of this book was named a member of the committee.

Dr. Wylie is professor of astronomy in the University of Iowa, where his years of practical experience in teaching have given him an excellent background for the writing of such a book as this.

The first part, consisting of six chapters, treats of the celestial sphere and its fundamental circles; the earth, its motions and its atmosphere; the change of seasons and the calendar; the constellations and the navigation stars. Both northern and southern circumpolar star charts are included, besides twelve excellent star charts for 40 degrees north latitude. For our fliers in southern latitudes, it would have been helpful to have had charts for latitudes below the equator, since the constellations appear and "behave" so differently where Orion and others are "up-side-down."

The second part, consisting of three chapters, treats of meteorology—winds, weather, clouds and weather forecasting. Beautiful photographs of the various types of clouds and other atmospheric phenomena are shown.

The third part, also consisting of three chapters, treats of maps and mapmaking, longitude and time, and celestial navigation. In this section the text is supplemented by numerous helpful illustrations.

The fourth part, consisting of eight chapters, is really a survey course in general astronomy, and is not to be considered a "required" part of the course. Presumably it has been included for those pilots and navigators, who may not have had a regular course in astronomy, but who may become interested in knowing more about the sun, moon, planets, stars and galaxies.

There are several small mistakes which will doubtless be corrected in future printings. Perhaps the most serious is the statement on page 219 that "the *astronomical day* commences at noon of the civil day of the same date." The so-called "astronomical day" begins at midnight, and this has been true since January 1, 1925.

The book is most attractive, the more so on account of the abundant excellent illustrations. It is practical and well suited for its purpose.

CLYDE FISHER

[1] *Astronomy, Maps and Weather.* C. C. Wylie. Illustrated. x + 449 pp. 1942. Harper and Brothers.

STRATEGIC MATERIALS AND NATIONAL STRENGTH[1]

THE Federal Government itself has not done a great deal to enlighten the public as to the reasons for the curtailment of various supplies because of the war. Of the several books which have appeared from private sources in the last few months on the general subject of war-time shortages, "Strategic Materials and National Strength" by Harry N. Holmes, despite its heavy title, is one of the smallest. For the general layman it is one of the more satisfactory books of this group since it makes rather clear in abbreviated and non-technical form the reasons for the need of wartime rationing of household and family supplies, as well as for the strict allocation of the materials of war industry.

[1] *Strategic Materials and National Strength.* Harry N. Holmes. Illustrated. v + 106 pp. $1.75. November, 1942. Macmillan Company.

An impression of authority and accuracy surrounds the writing, for Dr. Holmes is professor of chemistry at Oberlin and is currently (1942) president of the American Chemical Society. The style of writing is terse; some might call it concise, others abrupt. The inside-covers of the volume have maps showing the chief foreign sources of strategic materials; otherwise the book is scantily illustrated.

In addition to listing strategic materials, and describing the changes in requirements since 1917, Dr. Holmes gives interesting chapters on the development of synthetic rubber and of new sources of natural rubber, on the "Metals of Mars," on foods, vitamins and clothing, and on many other materials which affect all of us. There is even one chapter on "Fortunate Abundance." It is a commentary on the rapidity of changing conditions that a book written in May, 1942, mentions the fuel oil shortage only in these terms: "Heavy loss of tankers and inadequate pipe lines combine to create a liquid fuel shortage in some eastern states" (p. 62).

An important purpose of the book is to present the need for guarding the future. Dr. Holmes believes that several things might, and should, be done to prevent the future repetition of the stringencies of the present. The principal task should be the creation of stock-piles of strategic materials as soon as the war is over. Perhaps "reservoirs" is a better word since the materials need not be static, though held in reserve for emergency use. Material reserves represent, in Dr. Holmes' opinion, such an important national strategic potential that he believes they might actually control the balance of power and, assuming a continuation of our American inclination toward peace, prevent the recurrence of war.

A. C. Swinnerton

TURTLES OF THE UNITED STATES AND CANADA[1]

The author has made this book an excellent natural history of the turtles of the United States and Canada for the many who have kept or do keep pet turtles in the bathtub, for the layman and the naturalist.

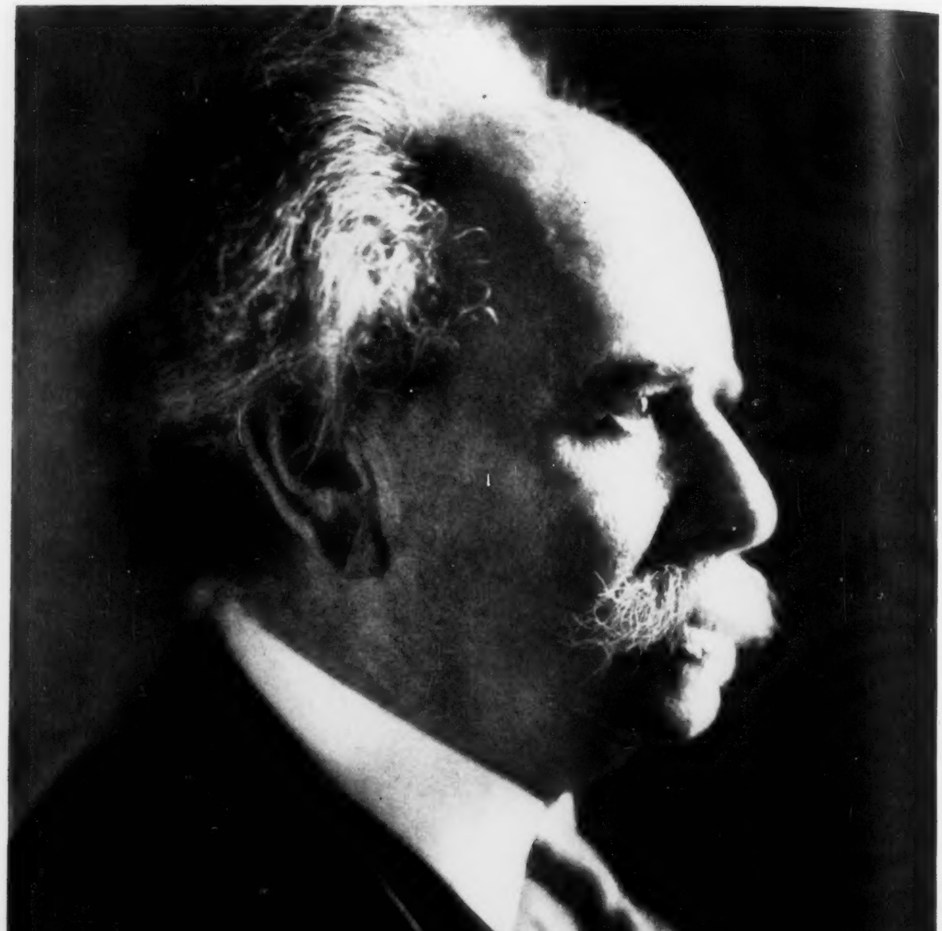
There are chapters dealing with the structure and relationship of a group of reptiles some 175 million years old and still thriving; others on food and feeding, enemies and defense, relation to man, and even on the care of baby turtles. Keys for the identification of the different groups and the species are so excellent that one deplores their absence in certain cases, and identification is made comparatively simple by the ninety-nine excellent photographs of living specimens, most of them taken by Mark Mooney, Jr.

After a discussion of turtles in general and their classification, each species is described with notes on habits and distribution. There is a good bibliography, and a list of all known species of the territory considered, with common and scientific names and a helpful index.

A most welcome book.

W. M. Mann

[1] *Turtles of the United States and Canada.* Clifford H. Pope. Illustrated. ix + 337 pp. $3.75. 1939. Alfred A. Knopf, Inc.



FRANZ BOAS, 1858–1942

THE PROGRESS OF SCIENCE

FRANZ BOAS, ANTHROPOLOGIST

When Franz Boas died on December 21, 1942, he had long been a historic figure. To appraise his services to anthropology, then, seems comparatively easy. However, to render that contribution intelligible to a wider public is a formidable task. For Boas was not the bearer of any simple new message. Thousands, it is true, have been impressed by his championship of the "lower" races, and that fact renders his place secure in the intellectual history of the times. But though he discussed the issue in the light of modern knowledge, his position—long anticipated by earlier thinkers—constitutes, from a professional angle, a lesser claim to distinction. In short, his greatness rests not on some one startling discovery, but on the totality of his output, the total impact of his personality upon the young science to which he turned as his major interest in the eighties of the last century.

Let us visualize the scene when Boas visited the Central Eskimo on his first expedition in 1883. Notable, even epoch-making, work had already been achieved in the science of man, but it had been the work of others than trained anthropologists, for such were not in existence. Boucher de Perthes was an amateur prehistorian, Edward B. Tylor had taught himself anthropology after stimulation by another amateur prehistorian. Paul Broca, Rudolf Virchow, Adolf Bastian were all medical men; Lewis H. Morgan practiced law; F. W. Putnam was a geologist. Boas' contemporaries and immediate successors include zoologists like A. C. Haddon; physicians like Karl von den Steinen, F. von Luschan, Paul Rivet, W. H. R. Rivers; linguists like Wilhelm Schmidt; and he himself started as a geographer schooled in physics and mathematics. His doctoral dissertation at Kiel dealt with the color of sea water; among his earlier treatises are critiques of psychophysical methods, articles or reviews on icebergs, the topography of Hudson Bay, and the theory of map projection.

Considering Boas' beginnings and the activities of his compeers, nothing is more remarkable than his systematic self-professionalization when he had once decided on an anthropological career. For by this time techniques of diverse type had ripened or were ripening in the several branches of the science, and Boas heroically strove to master them all. In physical anthropology, we may conjecture, he acquired metric techniques from Virchow or his Berlin associates; but Boas soon recognized the importance of statistical methods for the investigation of variable phenomena and devoted years to the sedulous but critical study of Karl Pearson's treatises. Still more remarkable was his control of the philologist's tricks, including phonetics; whoever witnessed his discussions with professional linguists realized that they accepted him as in the fullest sense their peer. Ethnographic methods had not yet been fully established when Boas began his career, and he not only assimilated current approaches, but, more than most, helped towards their progressive refinement. With the intense specialization of the last decades Boas realized that no future investigator could hope for a uniform mastery of these several fields, but he fostered as much breadth in training as the varying capacities and temperaments of his pupils would bear.

This self-taught anthropologist, then, aimed at training professional research men. He schooled them in the spirit and the tools of inquiry, concerned solely with the advancement of knowledge. To convey cut-and-dried information was thoroughly distasteful to him. It is literally true that any of my better under-

graduate majors has a far better knowledge of general anthropology than I had when Boas approved my doctoral dissertation.

In his own opinion (letter to me, Dec. 30, 1937) Boas had contributed to "just three things,"—a reëxamination of the basis of physical anthropology; a presentation of languages on Steinthal's principles, *i.e.*, from their own, not an outsider's point of view; and "a more thorough empirical understanding of cultural life." This restrained self-appraisal hardly clarifies the extent of his influence. I shall venture to expand it by a psychological interpretation.

Boas' mind was in the highest degree critical, but not in the sense of sterility. Exacting as to evidence, and dealing with the most complex of phenomena, he abhorred facile generalizations and all-embracing systems. But this caution was not that of timidity, but of daring. The fact that a view was current among professionals, that it was approved by men whom he himself highly esteemed, counted for naught in the absence of supporting evidence. I have heard him reject a craniological interpretation of Virchow's, and he vigorously dissented from some of Tylor's conclusions. In short, Boas, like all great scientists, regarded things as they are, with complete freedom from the shackles of tradition. When blending inheritance still seemed an obvious conception, he reported segregation in the stature of half-breeds; when others still attached fetichistic value to the cephalic index, he showed that it was not a racial criterion of *primary* value; when virtually all ethnologists assumed as axiomatic the priority of matrilineal descent, he challenged the postulate as a result of his own findings.

To this freedom from authority Boas added an unusual capacity for detecting fruitful fields of inquiry, of giving to old problems an altogether new twist. It is merely necessary to compare his researches on primitive art with those of even his most gifted coëvals to appreciate this quality. His originality appeared likewise in his cavalier redefinition of such concepts as "totemism," which he recognized as the result of premature classification.

De mortuis nil nisi verum. To readers who had never met him, who had never viewed him either in historical perspective or in his total intellectual effort, his influence remained an enigma; one might well read a thousand pages of his output without finding more than a faithful, intelligent collector of raw detail. But even deeper knowledge might fail to attract, since ultimate judgments in science involve nearly as much individual taste as in the arts. Anyone held captive by the literary qualities of Tylor, let alone, J. G. Frazer, was bound to be repelled by the bleakness of Boas' diction; and even as to the more vital matter of organization his negligence of form sometimes transcended credibility, so that his books have been called negations of the idea of a book. Certainly his warmest admirers cannot be happy over a professedly general volume on *Primitive Art* nearly a third of which is devoted to the meticulous consideration of a single area. Boas must further leave unsatisfied those numerous minds who crave a scheme that shall enable them neatly to pigeonhole every item of experience.

But to congenial spirits this very renunciation, with its compensatory flashes of insight into an indefinite number of special problems, will loom as the very embodiment of bald grandeur. They will recall with pride that they had "seen Shelley plain," that they entered sympathetically into that ever searching, austere, yet original mind; and they will view his passing with sentiments not unlike those which Browning ascribes to the disciples of his Grammarian:

> Lofty designs must close in like effects:
> Loftily lying,
> Leave him—still loftier than the world suspects,
> Living and dying.

ROBERT H. LOWIE

DR. EDWIN H. ARMSTRONG, EDISON MEDALIST

It has been announced that Dr. Edwin H. Armstrong, professor of electrical engineering, Columbia University, is to be awarded the Edison Medal by the American Institute of Electrical Engineers "for distinguished contributions to the art of electrical communication, notably the regenerative circuit, the superheterodyne circuit, and frequency modulation." The presentation ceremony took place on the evening of January 27, in the Engineering Auditorium, New York City.

This award was established by associates and friends of Thomas A. Edison to commemorate his achievements of half a century. It is the highest distinction conferred by the Institute. Dr. Armstrong is particularly worthy of this honor as he has made several major contributions to radio engineering during the past thirty years. The first came in 1914 with the publication in the December 12 issue of the *Electrical World*, of "Operating Features of the Audion" in which he presented the correct explanation of the functioning of the audion, or the electron tube as it is now called, as

a detector and as an amplifier with conclusive experimental proof. These results did much to stimulate the interest of amateurs and engineers in the use of the audion, for previous to this time the principles of operation were not generally understood and there was a wide divergence of opinion, even among those who were using the tubes.

With Armstrong's disclosure of the regenerative circuit, in 1915, what had been a keen interest became, in the 1920's, a consuming passion until most everyone was building radio receivers. Regeneration provided an inexpensive means of obtaining greatly increased sensitivity and as a by-product increased selectivity. It was directly responsible for the rapid growth in broadcasting during this decade.

While serving with the Signal Corps in France during the first World War, Major Armstrong developed the superheterodyne receiving system. This method makes it possible to design the intermediate stages of amplification for any desired frequency band, without reference to the frequency of the incoming signal; thus the intermediate amplifier may be permanently adjusted for the most favorable operating condition. It also provides a means of separating signals on adjacent channels which otherwise might interfere. This type of receiver is now almost universally used.

In 1920, Professor Armstrong developed the super-regenerative receiver which produced an extremely sensitive detector at a very low cost. It was used in the early two-way ultra-high frequency police systems and I understand that it is being used by the Germans in the present war.

The next problem to engage the attention of Professor Armstrong was that of improving the quality of broadcast service. Everyone is familiar with the distortions produced by static, other electrical sources, selective fading and the resulting garbled programs that too often mar reception. Professor Armstrong's proposal was to use frequency modulation to eliminate the foregoing sources of annoyance and at the same time to provide a fidelity and tonal range not possible with the narrow channels available in the broadcast band. While this problem has long been a challenge to radio engineers, Armstrong was first to make substantial progress towards its solution. In 1933, after years of research, he gave a demonstration in his laboratory, at Columbia University, to officials of the Radio Corporation and later submitted his system to them for field tests, but at the time they were more interested in television than frequency modulation. Two years later Armstrong presented a paper on frequency modulation and gave a successful demonstration before the Institute of Radio Engineers. The paper was published in the Proceedings for May, 1936. Despite all the promise of the system, industry showed no disposition to adopt it. However, Armstrong was so firmly convinced of the merit of frequency modulation that in 1937 he built a $300,000 station with his own money. Soon the Yankee Network became interested and was followed by F. M. Doolittle (WDRC), General Electric Company, Stromberg-Carlson, Radio Corporation, American Telephone and Telegraph Company and others. Much progress was being made when war was declared. There is no question but that the Armstrong system will be widely adopted as soon as peace comes, for it does eliminate static, selective fading and other distortion; fidelity and tonal range will be demanded by discriminating auditors.

Among the honors received by Professor Armstrong are the following: Medal of Honor of the Institute of Radio Engineers, 1917; Chevalier de la Legion of d'honneur, French Government, 1919; degree of Doctor of Science, Columbia University, 1929; the Egleston Medal,

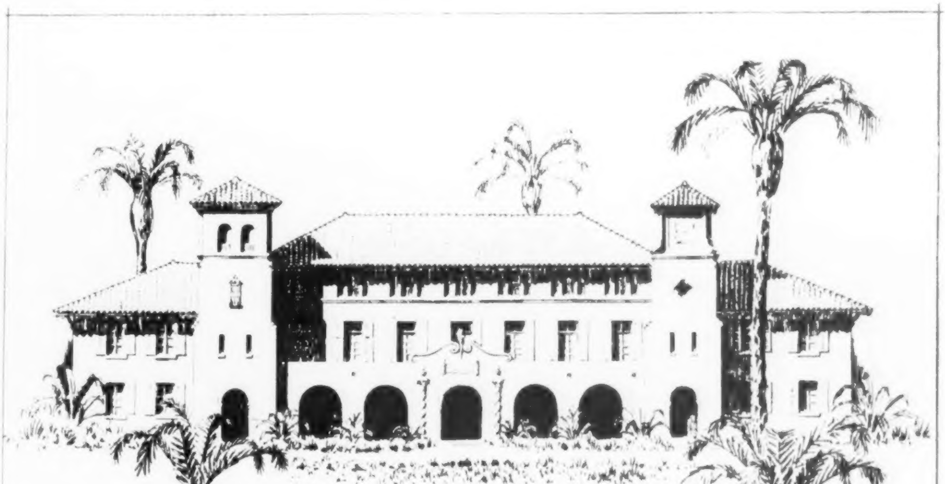
Columbia University, 1939; the Holley Medal, American Society of Mechanical Engineers, 1940; the Franklin Medal, Franklin Institute, 1941; the degree of Doctor of Science, Muhlenberg College, 1941; the John Scott Medal, awarded by the Directors of the City Trusts, Philadelphia, 1942. He also received one of the nineteen National Awards of "Modern Pioneer" by the National Association of Manufacturers, 1940.

H. M. TURNER

INTER-AMERICAN INSTITUTE OF AGRICULTURAL SCIENCES

FOR many years the need has been felt for a central organization to conduct long-range research projects in the agricultural sciences throughout the Western Hemisphere. The Eighth American Scientific Congress, held at Washington during May, 1940, recommended the establishment, in one of the Latin American countries, of an inter-American organization designed to carry out such research in agriculture. The Governing Board of the Pan American Union approved the By-laws of the Inter-American Institute of Agricultural Sciences on October 7, 1942, and recommended its establishment at Turrialba, Costa Rica, after an extensive study of plans for its organization and maintenance.

The immediate purpose of the Institute is the advancement of agriculture in the American nations through teaching, research, experimentation, extension activities, general education, and training in agriculture and related arts and sciences. The Board of Directors of the Institute is composed of representatives of the twenty-one American Republics on the Governing Board of the Pan American Union. A Technical Advisory Council, composed of one member from each nation, appointed by the respective governments, will consider questions of general policy and make recommendations concerning the advancement of the purposes for which the Institute is organized. There are two officers, the



THE INTER-AMERICAN INSTITUTE OF AGRICULTURAL SCIENCE
THE ARCHITECT'S DRAWING OF THE ADMINISTRATION BUILDING TO BE ERECTED IN TURRIALBA.

TURRIALBA VALLEY, SITE OF THE NEW INSTITUTE,
AS SEEN FROM THE SLOPES OF TURRIALBA VOLCANO AT AN ELEVATION OF APPROXIMATELY 5,000 FEET. THE TOWN NEAR THE CENTER IS TURRIALBA (ELEVATION 2,000 FEET). THE INSTITUTE WILL BE LOCATED AT A POINT TO THE LEFT OF THE CENTER OF THE PICTURE.

director, Dr. Earl N. Bressman, formerly director of the Division of Agriculture, Office of the Coordinator of Inter-American Affairs, and the secretary, José L. Colom, chief of the Division of Agriculture of the Pan American Union. The headquarters of the Institute are located in Washington, D. C., and other offices are to be maintained throughout the American Republics. Plans for the Institute also contemplate utilization of research facilities offered by several Latin American governments, such as the recently organized Experiment Station at Tingo María, Peru; the Agricultural Experiment Stations at Salta and Misiones, Argentina; the agricultural research center at Santiago de las Vegas near Habana, Cuba, and many others that have been offered as collaborating stations. Its activities, therefore, will not be confined to Costa Rica.

Turrialba, Costa Rica, was selected as an ideal location for the Inter-American Institute of Agricultural Sciences because, lying at an altitude of a little over two thousand feet, it offers within a distance of less than two hours by car or train an almost complete cross-section of Tropical American conditions. The program of the Institute will embrace the objectives outlined at the Eighth American Scientific Congress, which are: the promotion of a better balanced agricultural economy in the American Republics; the compilation of basic data on their agricultural problems; the development of a broader knowledge of plant and animal diseases and pests; and the training of future leaders in the agricultural field.

The Institute will play an important part in the war effort. As soon as it is completely organized, it will furnish ad-

vice to all official and other recognized agencies on the problems created by the war. It will strive to carry out the necessary research and will assume the responsibility of getting this work done. The Institute, as an applied research organization, will try to avoid duplication of services and activities of the various experiment and research agencies already working on the problems created by the war.

Building plans for the Institute in Turrialba have already been drafted and actual construction will start in the very near future. The decision to establish the Institute in Costa Rica was well-founded, as this country is one of the most progressive and democratic nations of this Hemisphere.

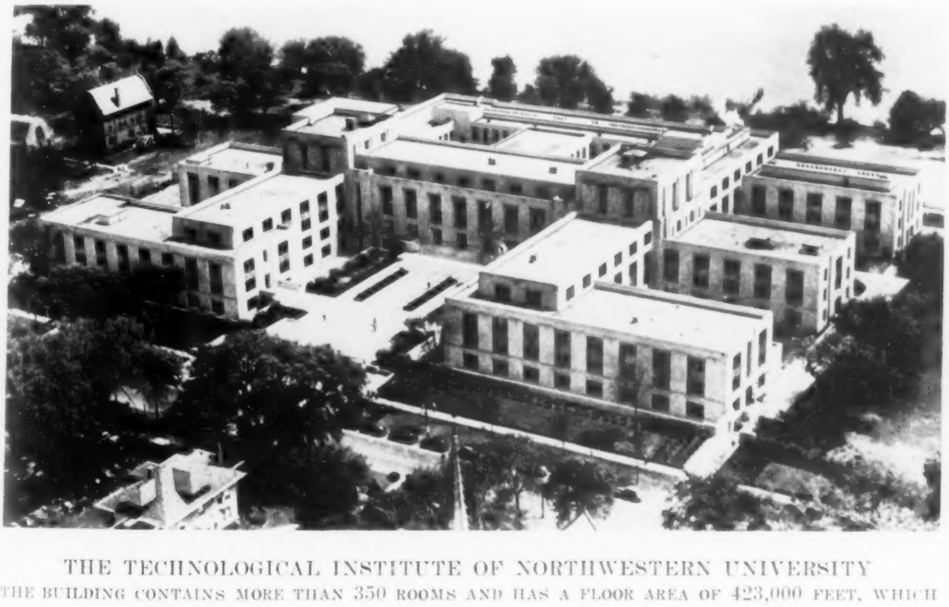
Organization of the Inter-American Institute of Agricultural Sciences is one of the most important projects in which the Pan American Union has participated. It is also one of the means best adapted to promoting closer cooperation among the American Republics.

L. S. Rowe,
Director General

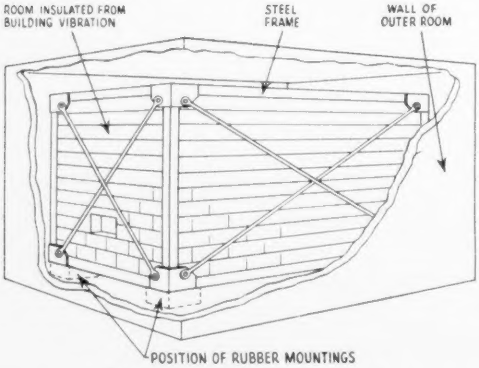
TECHNOLOGICAL INSTITUTE OF NORTHWESTERN UNIVERSITY

In June Northwestern University dedicated, on the Evanston campus, a new building for its Technological Institute. The gift of Walter P. Murphy, inventor and manufacturer of railroad equipment, the institute has three main objectives: (1) to provide training in engineering for a select group of young men; (2) to provide industry with skilled workers and executives; and (3) to provide facilities for research in problems related to industry.

The keystone of the institute's program is the cooperative plan whereby students alternate three months of study in the classroom with an equal period of work in industry. The institute operates on a normal five-year curriculum. The student spends his first year on the campus in classroom study, thereafter



THE TECHNOLOGICAL INSTITUTE OF NORTHWESTERN UNIVERSITY
THE BUILDING CONTAINS MORE THAN 350 ROOMS AND HAS A FLOOR AREA OF 423,000 FEET, WHICH MAKES IT ONE OF THE LARGEST EDUCATIONAL BUILDINGS IN THE WORLD.



THE SOUND-PROOF ROOM
LOCATED IN THE PHYSICS DEPARTMENT OF THE INSTITUTE. THE SMALL WINDOW AT THE LEFT IN THE WALL OF THE ROOM IS TO BE USED FOR TAKING READINGS.

alternating each quarter between the classroom and a job in industry. Half of the class thus remains in college while the other half is at work. The next quarter these groups are shifted. This alternating schedule continues until the spring quarter of the final year, when the entire class is brought back to the campus.

A POWERFUL TESTING MACHINE
THE TRANSVERSE-UNIVERSAL MACHINE, WHICH IS CAPABLE OF APPLYING TRANSVERSE LOADS UP TO 1,000,000 POUNDS.

Seventy large firms, located in twelve different states, are now cooperating with the institute. The industrial concerns afford the students opportunity for direct experience and in return these firms are provided with young men who have been carefully selected and taught.

The institute has been operating on the cooperative plan since it opened in 1939. Ovid W. Eshbach, dean of the Technological Institute, recently said of this program: "The cooperative system brings the young man into contact with the realities of our industrial system. It shows him the significance of the facts and principles which he has acquired through books and in his classes. It makes him inquisitive. The alternation of theory and practice enhances the value of both, for after all they are not separate experiences but complementary processes in learning."

The new $5,000,000 building provides a modern, well-equipped plant in which to carry out the purposes of the institute. The structure has ten acres of floor space, but its immensity is partially concealed by skilful disposition of its masses. The general arrangement of the building is that of two letter E's laid back to back and joined by a central structure. The center is occupied by the main auditorium, lecture room, library, student lounge and main offices, while each of the six wings is devoted to one of the major divisions—the departments of physics and chemistry of the College of Liberal Arts, and the departments of civil, chemical, electrical and mechanical engineering of the institute. Two of the future objectives of the institute are the addition of departments of aeronautics, mineral industries, and architectural engineering and the establishment of a graduate school in engineering research.

Basically, the general design of the building is functional; yet enough of the Gothic is suggested in its silhouette and decorative details to make it harmonize with other buildings on the campus.

The exterior is of Lannon stone with Bedford stone trim. The varied color of the Lannon stone and the relatively small size of its pieces invest it with a warmth and intimacy which otherwise might be lacking. This feeling is intensified in the spacious entrance court, where the use of a flat, paving brick combined with stone creates a pattern that brings this extensive space down to human scale.

An example of the facilities which are available to students and to research workers is provided by the department of physics. This department has a special laboratory of explosion-proof construction in which it is possible to produce six gallons of liquid air and two-and-one-half gallons of liquid hydrogen an hour. Cold rooms, x-ray rooms, electrical laboratories, spectroscopic laboratories and heat and pyrometry laboratories comprise some of the important facilities for teaching and research. One of the features of the department is a sound-proof room which is being used for theoretical research. The room, which is inside another concrete room, is mounted on rubber. It weighs 50 tons and its walls are covered with 18 layers of muslin which absorb 98 per cent. of air-borne sound and mechanical vibrations from the outside.

ENTRANCE COURT OF THE INSTITUTE

THE ARCHITECTURE OF THE BUILDING IS MODERN GOTHIC, TO CONFORM WITH OTHER NEW BUILDINGS ON THE CAMPUS OF NORTHWESTERN UNIVERSITY.

In order to provide the environment and facilities through which students may develop their fullest possibilities and industry may profit from new knowledge and skill, the institute has been provided with more than $1,600,000 worth of new scientific equipment. Although some of the equipment is unique and affords opportunities for special types of investigation, the principal purpose has been to provide well-rounded facilities adapted to the needs of student training and general research.

No time has been lost in putting the

facilities of the institute to use. Many important research projects are now under way, and the essential tasks of furnishing technicians for the army and the navy and of training men and women for jobs in war industries are in full swing.

The present enrolment of the institute in its full-time program consists of about 850 students, of whom 340 are freshmen who entered last summer and fall. This freshman class was selected from approximately 750 applicants.

There are now 1,000 sailors enrolled in the Naval Radio Operators' School at Northwestern University, who do their class work in the Technological Institute. After a four-month course these men qualify as naval radio specialists. More than 100 men are also enrolled in the Army Signal Corps Officers' Training School, which has classes in the institute. Graduates of this course are commissioned in the Signal Corps, if they pass the physical examination.

One of the big problems of the war is that of getting trained personnel for skilled work in the defense industries. Through a series of constantly enlarged, evening, tuition-free courses the Technological Institute has provided more than 2,200 men and women with the background in industrial engineering they need to take over important jobs. A new program, not bearing academic credit, offers training in 40 subjects of engineering directly related to the war effort to more than 2,000 special students.

Dean Ovid W. Eshbach of the institute said recently that there are more than 5,000 men and women now taking work at the institute. Directly or indirectly all of these individuals are preparing for tasks which are vital to the war effort. But the leaders of the institute even now are looking forward to the future. The day will come when the last shot shall have been fired. It is then, as Secretary of Commerce Jesse Jones said at the dedication of the institute last June, "That those who have had the opportunity of studying at seats of learning will again play a leading part, for it will take as much skill and knowledge in our reconstruction program to turn our industrial and economic machinery back to its peace-time services as it has taken to convert this machinery to war service."

Since the foregoing was written Northwestern University has been notified of an additional gift of $20,000,000 from the estate of Walter P. Murphy, who died on December 16. This is the largest bequest ever made to higher education by a citizen of Chicago, and is probably the largest in the nation since 1924, when James B. Duke willed $40,000,000 to Trinity College (now Duke University).

Mr. Murphy specified that the fund should be used to develop, maintain and operate the Technological Institute of Northwestern University, which was founded in 1939 with a gift of $6,735,000 from the Walter P. Murphy Foundation. Beyond this restriction, he placed no limitations on the use of the bequest, leaving to the board of trustees of the university the final decision as to future management.

The donor expressed a desire that as much as possible of the principal should be held intact and used for endowment of the institute. At the same time he empowered the trustees to spend portions of the principal from time to time, and all or any part of the annual income, for additional buildings, equipment, professorships, scholarships, books, research and such other purposes as the trustees think necessary to the proper operation of the institute. He also specified that the institute, as a part of its operations, may give instruction in science to other than engineering students of the university.

The present bequest is Mr. Murphy's fourth benefaction to Northwestern. He made two gifts in 1923, one of $5,000 to the College of Liberal Arts, and one of

$10,000 to the School of Commerce. In 1939, through the Walter P. Murphy Foundation, he gave $6,735,000 to erect and equip on the Evanston campus the new building of the institute.

E. H. S.

AVALANCHES IN THE ALPS

THERE are several kinds of avalanches: those known as dust avalanches, compact snow avalanches and ice avalanches. Of these three kinds dust avalanches are the most to be feared, for, while the others fall according to certain well-known rules and at particular times of the year, these avalanches are erratic in their movements, uncertain in the periods at which they descend, and most terrible in their results. Dust avalanches consist of cold, dry, powdery snow, which, falling on a slope of grass, slides off on the slightest provocation.

Often, if a bit of overhanging snow falls on the upper part of a hillside, or if an animal disturbs the newly fallen mass, or perhaps if a gust of wind suddenly detaches it from the surface on which it rests, the whole accumulation begins to move down, gently and quietly at first, and then with ever increasing power and a deafening roar, uprooting trees, carrying away chalets and whatever happens to be in its course, and leaping like a huge stream of spray-covered water from precipice to precipice, till it makes one final bound across the valley, the impetus of its course frequently carrying it up for some distance on the opposite slopes. The wind which accompanies such an avalanche is far more powerful than a raging hurricane, and it often levels trees and buildings, forces in windows and doors, and carries heavy objects an incredible distance.

In February, 1888, on the occasion of the fall of two great avalanches into Saas-Grund, most of the windows and doors in the village were forced in from the pressure of air. Tschudi states in his "Monde des Alpes" that such avalanches will sweep châlets and trees from the ground and carry them, whirling like straws in a storm, through the air, dropping them at a distance of upwards of 400 feet. Châlets filled with hay, and quite uninjured, have been found, it is said, some two hundred yards or more from the termination of the débris of an avalanche, having been blown across the valley by the blast of wind ahead of the avalanche.

In the year 1689, an enormous avalanche which, in the annals of the Grisons, is spoken of as the most fearful one on record in the Canton, came down from the heights above the village of Saas, in the Prättigau, and demolished 150 houses. Amongst the débris which had been swept by the avalanche to a considerable distance, a rescue party discovered a baby lying safe and sound in his cradle, while six eggs were found uninjured in a basket close at hand.

Swiss Federal Railroad

AVALANCHE PROTECTIVE MEASURES

TAKEN BY THE SWISS FEDERAL RAILROADS ON THE ST. GOTHARD LINE, BETWEEN ERSTFELD AND AMSTEG, NORTH OF THE GREAT TUNNEL.

SÉRACS IN THE VICINITY OF THE RHONE GLACIER IN SWITZERLAND

W. Lottenbach

THE DESCENT OF THE WETTERHORN AVALANCHE NEAR GRINDELWALD
IN THE BERNESE OBERLAND, SWITZERLAND. IT IS AN EXAMPLE OF THE DANGEROUS DUST TYPE.

K. Egli

SWISS SOLDIERS IN THE ALPS MEASURING AND STUDYING THE SNOW
TO DETERMINE WHETHER AND WHEN AN AVALANCHE IS DUE TO DESCEND TO THE VALLEY.

K. Egli

A SWISS ARMY SKIER
ON DUTY IN THE ALPS ABOUT TO SET OFF AN EXPLOSIVE TO BRING DOWN AN AVALANCHE BEFORE IT HAS HAD A CHANCE TO CAUSE DESTRUCTION.

Another sort of avalanche is formed by the sudden descent of an overhanging mass of snow. The slightest movement in the air will often suffice to break the cornice, and it straightway goes rolling down the slope. Such avalanches are not usually much to be feared, though a notable exception to this fact was furnished on the Bernhardino Pass when the mass of falling snow, overtaking the post in its passage, carried thirteen persons, and a number of sledges, over the precipice into the gorge beneath.

Dust avalanches of freshly fallen snow are very frequently met with in summer by climbers amongst the higher peaks of the Alps. It was an avalanche of this kind which caused the Matterhorn accident of 1887, in which a number of persons fell an estimated distance of six to eight hundred feet.

It is reported that in the winter of 1916–1917, during the World War, about ten thousand officers and soldiers were killed in the Tyrol in a single day by avalanches rushing down its steep mountain sides. Often conditions favorable for avalanches are recognized and the inhabitants avoid so far as possible the most dangerous places. For example, in early December, 1940, snow fell steadily, becoming deeper and deeper on perilous mountain slopes. The people living in the valleys below the heights passed anxious days. Finally, on December 13 and 14, avalanche after avalanche thundered down into the valleys, causing terrible destruction and claiming several human victims.

In order to reduce the serious losses of life from avalanches, the Swiss army, under General Guisan, began the scientific investigation of them in 1939. The studies were carried out on the mountains where avalanches occur. They included not only measurements of snow and determination of conditions favorable for avalanches, but also life-saving procedures in alpine conditions. One of the best methods of forestalling them is to start them with mine throwers before the snow has accumulated to dangerous proportions. By this method the great Dratscha snow field near Davos is being regularly reduced from which some years ago an avalanche descended and buried an entire train of the Rhaetian Railway.

F. Dossenbach